

Silviculture Treatments for Ecosystem  
Management in the Sayward (STEMS)  
Establishment Report for STEMS 2, Elk Bay

2009

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Establishment Report for STEMS 2, Elk Bay**

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Louise de Montigny and Gord Nigh



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Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) is a large-scale, multi-disciplinary experiment that compares forest productivity, economics, and public perception of seven silvicultural regimes replicated at three sites in the Sayward Forest.

The STEMS experiment uses silvicultural systems and treatments to create diversity in forest structure that results in a variety of canopy layers (vertical structure) and spatial patchiness (horizontal structure) to enhance biodiversity and wildlife. The STEMS experiment examines seven different treatment regimes:

1. Extended Rotation with Commercial Thinning
2. Clearcut with Reserves
3. Extended Rotation (non-treatment control)
4. Uniform Dispersed Retention
5. Group Selection
6. Modified Patch Cuts
7. Aggregate Retention

These silvicultural regimes create a range of gap sizes and frequencies that emulate natural variation in forest structure.

This Technical Report describes the establishment of the second replication of STEMS starting in 2003 near Elk Bay in the Sayward Forest. Treatment units were harvested in 2005. STEMS 2 stand conditions differ from STEMS 1 with higher densities and proportions of western hemlock (*Tsuga heterophylla*) and moister biogeoclimatic site series. Ongoing studies include:

- Tree growth and stand development, including understorey vegetation
- Regeneration and light availability
- Windthrow, mortality, and coarse woody debris recruitment
- Harvesting production and impacts of residual tree damage and soil disturbance (in partnership with the Forest Engineering Research Institute of Canada [FERIC])
- Visual quality and public response

The results of this experiment will be used to determine how silviculture treatments can be used to create healthy, resilient forests that continue to provide the range of timber and non-timber forest products and ecosystem services demanded by society.



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Clearcutting has been the primary silvicultural system applied on the coast over the last century and we have become very skilled at timber management on many types of terrain in varying climates. However, with increasing public demand for forests with multiple uses including timber, recreation, non-timber forest products, and diverse wildlife habitat, clearcutting has become increasingly socially unacceptable. The forest industry is increasingly using alternatives to clearcut harvesting, but there is currently a lack of reliable scientific data to support decision-making regarding the use of alternative harvesting practices. Existing research studies have addressed various components of differing partial cutting systems, mostly in old-growth stands. However, no examples are available on the coast of silvicultural systems in second-growth stands, other than clearcutting, that have been systematically applied over an extended period of time and area, and that have the data collection necessary to make sound quantitative comparisons of their biological, financial, and social results. As well, the threat of climate change and the consequences to forest ecosystems (such as the mountain pine beetle epidemic) has resulted in the need to explore silviculture treatment options that will ensure that our healthy, resilient forests continue to provide the range of timber and non-timber forest products and ecosystem services demanded by society.

The Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) project is a large-scale, multi-disciplinary experiment that compares forest productivity, economics, and public perception of seven treatments replicated at three sites in the Sayward Forest. The treatments include five different silvicultural systems: clearcut with reserves, modified patch cuts, group selection, aggregate retention, and uniform dispersed retention, which are compared against two extended rotation options, with and without commercial thinning. The first replication was established in the Snowden Demonstration Forest in 2001 (de Montigny 2004). This Technical Report describes the establishment of the second replication near Elk Bay. A third replication is underway.

STEMS is a replication of the "Silvicultural Options for Harvesting Douglas-fir Young-Growth Production Forests" in the Capitol Forest near Olympia, Washington, developed jointly by the managers of the Washington State Department of Natural Resources and the scientists of the Pacific Northwest Research Station. The decision to replicate the treatments in the Sayward Forest was based on the similarity of knowledge gaps in the Sayward Forest and the Capitol Forest and because replication in Washington and British Columbia results in greater statistical power and ability to extrapolate over a wide geographic area.

STEMS is a long-term, multi-disciplinary, silvicultural systems experiment with a planned life of 80 years; future stand treatments and the monitoring of permanent plots will be over the course of one rotation. Given the long-term nature of the STEMS experiment, this Technical Report documents in detail the experimental design and methodology and the schedule of further treatments and maintenance needed to maintain the integrity of the experiment. The report also summarizes the pre- and post-treatment baseline information that will provide current and future researchers and forest managers the necessary information to continue to derive maximum benefit from the STEMS experiment for solving current and future forest management prob-

lems. The results of this experiment will be used to improve environmental management and policies because results can be directly interpreted operationally due to the large-scale, replicated experimental design. The information will be especially relevant for forests with high multiple-use demands.

## **2 STUDY DESCRIPTION**

---

The STEMS experiment uses silvicultural systems and treatments to create diversity in forest structure that results in a variety of canopy layers (vertical structure) and spatial patchiness (horizontal structure) to enhance biodiversity and wildlife. These silvicultural regimes create a range of gap sizes and frequencies that emulate natural variation in forest structure. The experiment examines seven different silvicultural systems treatment regimes:

1. Extended Rotation with Commercial Thinning
2. Clearcut with Reserves
3. Extended Rotation (non-treatment control)
4. Uniform Dispersed Retention
5. Group Selection
6. Modified Patch Cuts
7. Aggregate Retention

### **2.1 Experimental Design**

The STEMS experiment has a randomized complete block design with seven treatments and three replicates in the Sayward Forest. Stand growth and yield information is based on repeated measurements on a grid of permanent plots, maintained for the life of the experiment. Supplementary short-term studies, including harvesting costs and visual impacts, are being conducted in co-operation with other organizations.

At STEMS 2, each of the seven treatment regimes was randomly assigned to one of seven treatment areas, which is the basic experimental unit. The minimum acceptable area required for each treatment unit varies with treatment, being less for those that produce homogeneous stand conditions (10-ha clearcut) than for those that result in patches or sparse distribution of residual trees (35 ha for the patch cut). Treatment units are described more thoroughly in section 3.4.

The STEMS experiment is part of a larger study that includes three replications of the treatments at the Capitol Forest near Olympia, Washington (Curtis et al. 2004). This study is officially titled "Silviculture Options for Harvesting Young Growth Production Forests," but for simplicity will be referred to here as the Capitol Forest Project. The decision to replicate the treatments in the Sayward Forest was based on the similarity of knowledge gaps in the Sayward Forest and the Capitol Forest. Both need sound quantitative information about how alternative practices affect stand growth and yield, ecosystem process and function, economic costs and returns, and public response to visual appearance. Collaboration between the STEMS experiment of the B.C. Ministry of Forests and Range and the Capitol Forest Project of the U.S. Forest Service will greatly enhance the statistical power of the overall experiment and will allow the extrapolation of results over a wide geographic region.



## 2.2 Goals and Objectives

The overall goals of the STEMS experiment are, within mature second-growth stands in the Sayward Forest:

- to create replicated examples of alternative harvest practices and silvicultural regimes that can be used as demonstration areas by foresters and planners in ecosystem management;
- to provide quantitative information for evaluation of feasibility and costs of alternative regimes and of their long-term effects on production of timber volumes and values and other non-timber values; and
- to evaluate the effectiveness of contrasting silvicultural systems in reducing environmental and visual impacts of forestry operations, while supplying high timber outputs over time.

The STEMS project has both scientific and extension objectives:

1. Scientific
  - a. To quantitatively compare forest productivity (including residual trees, regenerating trees, understorey vegetation, light environments, mortality and windthrow, and coarse woody debris) under contrasting silvicultural systems over an extended time period.
  - b. To quantitatively compare timber outputs, production costs, and operational factors associated with harvesting (including post-harvest residual tree damage, soil disturbance and compaction, and slash loading).
  - c. To quantitatively compare the public response to the various silvicultural treatments.
2. Extension
  - a. To create three replicated examples of five silvicultural systems and two extended rotation treatments that can be used as demonstration areas by foresters and planners in ecosystem management and as experimental areas for scientists studying ecosystem dynamics.
  - b. To facilitate the interpretation of forest management implications and the application of seven silvicultural systems or extended rotation treatments by providing current information about the biological, economic, and social results of the STEMS project to all interested audiences in a timely and appropriate manner.

## 3 SITE PLAN

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The site plan is required by licensees under the Forest Practices and Planning Regulations of the *Forest and Range Practices Act* and characterizes the standard units for the area (in this report, standard units and treatment units are synonymous). Included is tenure information and legal requirements; resource assessments such as for riparian areas, pests, diseases, wildlife, etc.; harvest plans such as the silvicultural system, leave trees and retention area functions; and ecological information that provides the rationale for stocking standards, site preparation, planting, and other stand tending practices. The site plan is retained until all requirements of the plan have been met, in this

case over the course of one rotation. Information from the STEMS 2 Site Plan (Swanson 2005) has been included in this Technical Report for completeness and for ease of access.

### 3.1 Site Location

The STEMS 2 site is located about 40 km north of the city of Campbell River near Elk Bay on the east side of Vancouver Island (50°20' N, 125°28' W), within the Strathcona Timber Supply Area (TSA). The area is within the Sayward Landscape Unit (established 2003), and the licensee for that part of the TSA is International Forest Products Limited (Interfor). The tenure for the area is A19232 (map sheet 92Ko33).

The area is less than 1 km west of Discovery Passage (on the Strait of Georgia), within the wetter subvariant of the Very Dry Maritime Coastal Western Hemlock subzone (CWHxm2). This zone is characterized by warm, dry summers and moist, mild winters with relatively little snowfall; growing seasons are long and feature water deficits on zonal sites (Green and Klinka 1994). The soils are well-drained and strongly podzolized, with a forest floor 10–30 cm deep, and distinct elluvial and illuvial (Ae, Ai) horizons across the entire slope.

The research site is split into two areas. Treatment Units (TUs) 1–5 are contiguous and cover 87.4 ha, including a wildlife tree patch (WTP) of 11.4 ha that borders on the extended rotation treatment. TUs 6 and 7 cover a 56.1 ha area and are located approximately 1000 m northeast of TUs 1–5 (see Figure A.1.1).

### 3.2 Ecosystems

Ecosystem mapping was done on a 150 ha area at a scale of 1:5000 using a contour base map. Minimum polygon size was 0.1 ha for pure site series units. Composite site series units were acceptable only if they were mosaics of site series that were not mapable. Plots were established at subjective locations based on modal stand and ground conditions. Plot size was 20 × 20 m, and five plots were sampled per site series for a total of 25 plots. Each plot was described or measured for site descriptions, vegetation, soils, and mensuration (all tree diameters > 5 cm dbh, and two dominant tree heights representing the leading species). Standards were based on Meidinger (1998).

Ecosystem mapping of the 150 ha area identified four site series (see Table 1 and Figure A.1.2). About 70% of the area was classed as 05 Cw – Sword fern (slightly dry to fresh soil moisture regime [SMR] and rich to very rich soil nutrient regime [SNR]). Another 20% of the area was 07 Cw – Foamflower (moist to very moist SMR and rich to very rich SNR), and 8% was zonal 01 HwFd – Kindbergia (fresh SMR and medium SNR). A small percentage of the area (less than 2%) consisted of site series 12 CwSs – Skunk cabbage (wet SMR and medium to rich SNR) occurring at the toe slopes and in riparian areas, but permanent plots were not established in these areas. Soils were predominantly Ortho Ferro-Humic and Ortho Humo-Ferric Podzols with a mormoder humus form (Green and Klinka 1994), a loamy or sandy-loam structure, a coarse fragment content averaging about 40%, and a depth averaging 50–80 cm. The ecosystem map was used to identify homogeneous treatment units, and to ensure that permanent plots were not established in very wet or very dry sites.

### 3.3 Resource Assessments

All resource assessments are found in the Site Plan (Swanson 2005). Assessments were done on resources referred to under Section 37 of the Operational Planning Regulations. Those particularly relevant to this Technical Report are summarized here (see Figure A.1.4 for corresponding maps).

TABLE 1 Site description of STEMS by treatment unit

Treatment unit	Area in each site (%)	Treatment description	Stand composition (% volume)	Site index	Aspect	Surface topography	Elevation (m)	Average slope (%)
1	05 (75%) 01 (20%) 07 (5%) 12 (+)	Extended Rotation with Commercial Thinning	Hw79 Fd17 Cw4 (BgDrPl)	33(Hw) 35(Fd)	NE(E)	Straight	90–167	18
2	05 (75%) 07 (25%) 12 (+)	Clearcut with Reserves	Hw75 Fd21 Cw8 Dr2 Bg1 (PlSs)	34(Hw) 34(Fd)	NE(E)	Straight	90–175	18
3	05 (65%) 07 (25%) 01 (10%)	Extended Rotation (non-treatment control)	Hw73 Fd16 Cw8 Dr2 Bg1 (Ss)	32(Hw) 37(Fd)	NE(E)	Straight	115–120	17
4	07 (60%) 05 (35%) 01 (5%)	Uniform Dispersed Retention	Hw72 Fd20 Dr5 Cw2 Bg1 (PlSs)	33(Hw) 38(Fd)	NNE(E)	Concave/convex	127–225	27
5	05 (75%) 07 (25%)	Group Selection	Hw75 Fd21 Cw1 Bg1 Dr2 (PlPwSs)	33(Hw) 37(Fd)	NE(N)	Straight?	108–200	27
6	05 (80%) 07 (10%) 01 (8%) 12 (2%)	Modified Patch Cuts	Hw88 Fd8 Cw4 (Bg)	34(Hw) 36(Fd)	NE/ENE	Straight	40–165	10
7	05 (70%) 01 (15%) 07 (10%) 12 (5%)	Aggregate Retention	Hw77 Fd17 Cw5 Bg1 (DrSs)	37(Hw) 36(Fd)	N/NE	Straight	37–160	26

1. Wildlife – Evidence of ungulate, bear, small mammal, and bird activity is common within and adjacent to the area. One bear den was located outside the northern boundary of TU7. Forest canopy removal within this block is expected to cause a temporary increase in the availability of forage species during early seral stages.
2. Fisheries – All streams and wetlands within and adjacent to the project area were assessed on two separate occasions by qualified staff (Interfor 2004) and the results are summarized in the Site Plan (Swanson 2005) and here. For more information about stream classifications and definitions, please see the *Riparian Management Area Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995a). There are 16 fish-bearing reaches and three wetlands in or adjacent to the plan

area. Stream reaches 1 and 10B are classified as s2 reaches and are located adjacent to the TUs 1–4. The Riparian Reserve Zones (RRZs) are located outside the block boundary. Portions of the Riparian Management Zone (RMZ) are located inside the block boundary and these will be harvested with retention left according to the planned treatment for that TU. For example, Douglas-fir (*Pseudotsuga menziesii*) in the RMZ of reach 10B inside of TU4 will be retained approximately every 15 m (about 75 sph). Stream reaches 29 and 33 are classified as s3 reaches and are located adjacent to TU6. RRZs are located outside the block boundary. Portions of the RMZ are located inside the block boundary, and these portions will be harvested. In the RMZ of reach 33 inside SU6, approximately 20–50 sph will be retained to reduce the risk of windthrow in the adjacent RRZ. To reduce the risk of windthrow, retained timber will be crown-modified using helicopters to top and thin the crown. Stream reaches 2B, 3B, 4B, 5B, 6B, 7B, 8B, 9B, 21B, 22C, 28B, and 32B are classified as s4 reaches and are located adjacent to TUs 1–3 and 7. Only reach channels 22C and 28B occur inside the block boundary. No machine traffic is allowed in stream channels, so where the stream channel occurs inside the boundary (reaches 22C and 22B), trees are felled and yarded away where practical. Riparian feature 13 is classified as w1 wetland. The RMA is outside the harvest boundary. Riparian features 14 and 15 are classified as w2 wetlands. The RMAs are outside the harvest boundary.

3. Recreation – There are no identified recreation areas within or adjacent to this stand.
4. Stand-level Biodiversity – A wildlife tree patch (WTP) totalling 11.4 ha (14% of the Silviculture Harvest Area) has been established to meet the biological diversity objectives of the Sayward Landscape Unit Plan (British Columbia Ministry of Sustainable Resource Management 2003). The WTP is predominantly a uniform mature/overmature stand of western hemlock (*Tsuga heterophylla*), Douglas-fir, western redcedar (*Thuja plicata*), with some grand fir (*Abies grandis*), western white pine (*Pinus monticola*), and red alder (*Alnus rubra*), and is classified as CWHxm2 site series 07/05 (01, 12). The patch will provide a variety of wildlife habitat requirements (nesting cavities and perching habitat, bear dens, security cover, travel corridors, etc.), retention of long-term coarse woody debris, and potential for wildlife trees and future snags.
5. Visual Resource Management – All visual quality assessments within and adjacent to the project area were conducted by Interfor staff and summarized in the Site Plan (Swanson 2005) and here. For more information about visual quality classifications and definitions, please see the *Visual Impact Assessment Guidebook* (British Columbia Ministry of Forests 2001). Portions of this block have been classified as having retention as a Required Visual Quality Condition (rvQC): TU 7, 30% Visual Sensitivity Unit (vsu) #664. Portions of this block have been classified as having partial retention as an rvQC: TU 2, 40% vsu #678; TU 3, 25% vsu #678; TU 6, 100% vsu #672; TU 7, 70% vsus #658/672). The remainder of this block is classified as non-constrained. Digital Terrain Models show that under the current harvesting systems only about 0.2–0.3 ha of the partial retention portion of TU 7 will be visible from one viewpoint, resulting in 4.2–6.3% visual denudation. The Sayward Land Use Plan allows 1.6–7.0% visual denudation for partial retention rvQC. The remainder of STEMS 2 was not visible from any other designated viewpoints.

6. Old Growth Management Areas – Old Growth Management Areas (OGMAS) have been set aside for deer and elk ungulate winter range adjacent to STEMS. The block boundary was located so that harvest activities do not affect adjacent OGMAS.
7. Forest Health
  - 7.1. Hemlock Dwarf Mistletoe (DMT) – occurs at low to moderate incidence throughout the area. Felling of all Hw > 3 m in height in the Net Area to Reforest will lower the incidence of mature infected trees. Regeneration of a mix of host and non-host species (western hemlock, Douglas-fir, western redcedar, grand fir, western white pine and red alder will mitigate the impact on future forest health and timber supply.
  - 7.2. White Pine Blister Rust (DSB) – occurs at moderate (to high) incidence throughout the area. Western white pine will make up less than 10% of well-spaced crop trees. Only asymptomatic western white pine will be acceptable as well spaced and free growing trees.
  - 7.3. Windthrow – assessments were performed in November 2004 (Mitchell 2004). Windthrow hazard was found to be variable due to the location, terrain, and different stand treatments throughout the study area. In general, windthrow hazard is (moderate to) high. Endemic southeasterly winds funnelling through Discovery Passage are expected to produce the highest source of windthrow, with periodic northwesterly winds less common but stronger. The windthrow analysis focussed on stand edges and residual timber inside the cutblocks. Stand treatments were prescribed to minimize windthrow at stand edges, in RMA's, and of retained timber in treatment units.

TU 1: Timber within one tree length along the boundary with TU 2 is to be crown-modified by helicopter to reduce wind resistance.

TU 4: Approximately 70% of residual timber, dispersed equally throughout the unit, is to be crown-modified using helicopter.

TU 5: No treatment is expected to be necessary immediately following the first pass. Windthrow hazard should be re-assessed prior to further entries to protect patches of timber that will be isolated after future harvests.

TU 6: Selected trees with the RRZ between Harvest Units 6 and 13 will be crown-modified using helicopters to reduce the risk of windthrow. Approximately 20–50 sph will be retained in the RMZ of reach 33 inside TU 6 (Harvest Unit 13), to reduce the risk of windthrow in the adjacent RRZ. Windthrow hazard should be re-assessed prior to further entries to protect patches of timber that will be isolated after future harvests.

TU 7: Spiral pruning will be conducted on selected aggregate retention patches (averaging approximately 70% of retained timber). Remaining patches will be left intact to monitor the effects of windthrow. Specific patches will be identified prior to harvesting operations.

In the event of minor windthrow in adjacent timber, trees will be managed as coarse woody debris. Some windthrow is expected and will be monitored for research purposes.

### 3.4 Treatment Units and Reserves

Treatment units were assigned by using the ecosystem map. The entire area was divided into seven roughly equal treatment units of about 15 ha, with largely 05 and/or 07 site series. The treatment units were subsequently num-

bered 1–7. The seven treatments were randomly assigned to each treatment unit. Once treatments were assigned, the boundaries of the treatment units were then adjusted to approximate the minimum acceptable area per treatment and modified based on harvest terrain, road location, and site series (see Figure A1.4). Boundaries were then surveyed and falling corners blazed, numbered, and mapped. These were used as reference points for subsequent plot layout.

Riparian reserves, wildlife tree patches, and deferred areas were mapped out based on resource assessments and the need for protection and enhancement of fish and wildlife habitat, stand-level biological diversity, and forest health.

Wildlife tree patches (WTPs) are reserves of aggregated trees designated for retention for not less than one rotation. The designated WTP encompasses the range of site series in the area. About 8% of the project area (11.4 ha) has been designated as WTPs.

The overall retention of existing forest structure over the areas is estimated at 51.7 ha or approximately 36% of the gross area. See Tables 1, 2, and 3 for treatment unit descriptions and area summaries.

### 3.5 Silvicultural Systems Prescription

The STEMS experiment consists of seven silvicultural systems or extended rotations randomly assigned to treatment units. The prescriptions for each treatment unit are described here. Air photos of the treatment units before and after treatment are shown in Figures A1.5 and A1.6.

#### Treatment Unit 1: Extended Rotation with Commercial Thinning

Management Objective: To retain sufficient numbers of trees on an extended rotation and to maintain sufficient growing stock to allow for at least one more thinning entry.

The prescription for TU 1 was based on modelling by the Tree and Stand Simulator (TASS) that estimated the culmination age (at maximum mean annual increment) of this stand to be 80 years if left unthinned. Model runs indicated that the thinning regime needed to maximize the gross merchantable volume of this stand if left for another 80 years is to thin the stand at age 65 (year 2005) to about 300 sph, and then again at age 105 (year 2045) to 150 sph. The final harvest would occur when the stand is aged 145 years in 2085.

TABLE 2 Area summary by treatment unit

Treatment unit	Total area under plan (ha)	Non-productive natural (ha)	Permanent access (ha)	Unharvested timber (ha)	Commercial thin (ha)	Net area to be reforested (ha)
1	15.9	0.1	0.8	-	15.0	-
2	12.5	0.1	0.5	-		11.9
3	12.1	-	0.5	11.6		-
4	15.4	-	1.3	4.3		9.8
5	20.1	0.3	0.7	14.0		5.1
6	30.2	0.5	1.5	21.0		7.2
7	25.9	0.4	1.0	0.8		23.7
WTPs*	11.4	-				
Total	143.5	1.4	6.3	51.7	15.0	57.7

\* Wildlife Tree Patches



TABLE 3 *Timber harvesting systems used in treatment units*

Treatment unit	Silvicultural system (age structure)	Treatment unit size (ha)	Opening size (ha)	Percent volume removal	Harvesting system
1	Extended Rotation with Commercial Thinning (even-aged)	15.9	0	64% removed in year 1 and 40% removed in year 40	Tracked feller-processors, tracked hydraulic log loader with a live heel boom
2	Clearcut with Reserves	12.5	12.5	100%	Feller buncher, feller processor, three tracked log loaders, two with heel boom grapples and one without
3	Extended Rotation (uncut control, even-aged)	12.1	0	0%	n/a
4	Uniform Dispersed Retention (two-aged)	15.4	15.4	95%	Feller buncher, feller processor, processor, four tracked log loaders, three with heel boom grapples and one without
5	Group Selection (multi-aged)	20.1	20 openings: 0.05-0.5 ha	25% to be cut each pass with four passes over 80 years	Feller processors, processor, five tracked log loaders, four with heel boom grapples and one without
6	Modified Patch Cuts (multi-aged)	30.2	6 openings: 0.7-2.0 ha	25% to be cut each pass with four passes over 80 years	Feller processor, three tracked log loaders with heel boom grapples
7	Aggregate Retention (two-aged)	25.9	25.9	97%	Feller buncher, feller processor, processor, three tracked log loaders with heel boom grapples

By that time, the 150 remaining sph are expected to have a merchantable volume of 575 m<sup>3</sup>/ha, a quadratic mean dbh of 62 cm, and a height of 41 m. The total gross merchantable volume for the life of the stand is expected to be 1235 m<sup>3</sup>/ha.

The first thinning will be systematic, leaving approximately 300 sph of dominant or codominant Douglas-fir, western hemlock, or western redcedar with good stem form dispersed evenly throughout the TU (approximately every 5-6 m). The second thinning is scheduled in 40 years (stand age 105, year 2045) and will space down to 150 sph. Retained timber will have ele-



ments of stand and forest structure from the pre-harvest stand to meet biodiversity objectives. The silviculture system will allow retention trees to provide greater than 50% influence to the harvest area throughout the unit.

#### **Treatment Unit 2: Clearcut with Reserves**

Management Objective: To create an even-aged structure.

All merchantable and unmerchantable trees on the site are to be cut. Harvest of the newly established stand is estimated to be in approximately 80 years. This system is well understood and has been included primarily to provide a direct quantitative comparison of costs and outputs with the other systems in the experiment. As such, and given the position of the road through the centre of the cutblock, a true reserve could not be left inside the cutblock without influencing growth and yield plots. Consequently, the reserve is the old-growth management area (OGMA) on the northern border (Figure A1.4).

#### **Treatment Unit 3: Extended Rotation (non-treatment control)**

Management Objective: To retain all existing trees on an extended rotation with no intermediate treatments.

These stands will be held on an extended rotation to test if untreated stands can achieve the late-seral attributes described in the Vancouver Island and Sayward Land Use Plans. This regime could be used for adjusting currently unbalanced age-class distributions, reducing visual impacts on the landscape, and enhancing biodiversity.

This treatment allows comparisons with productivity gains obtainable by the extended rotation with commercial thinning treatment regime and the other silvicultural systems. No harvesting or other stand management treatments are planned, but some wildlife and recreation enhancement activities may be done.

#### **Treatment Unit 4: Uniform Dispersed Retention**

Management Objective: To retain a component of the existing stand that over time will result in a bimodal stand structure. The primary objective of this retention is enhanced visual quality and biodiversity, not seed-tree regeneration.

Target residual stand structure is 40 sph, at approximately 15-m spacing. Reserved trees will be comprised of 100% Douglas-fir and will retain elements of stand and forest structure from the pre-harvest stand, for at least one rotation, to meet biodiversity objectives. Some windthrow is expected, so about 70% of residual trees dispersed equally throughout the unit will be crown-modified.

Future management: Leave trees are to be retained for one rotation (80 years). Trees that blow down or die will be assessed individually, but are generally not intended to be salvaged. The silviculture system will allow trees to provide greater than 50% influence to the harvest area throughout the unit. Influence is defined as the biophysical effects of forests or individual trees on the environment of the surrounding land; a retention system must maintain greater than half of the original forest area within the influence of surrounding trees, or trees retained within the harvested area, and create openings generally less than four tree heights across. Areas harvested will be regenerated to an even-aged stand of Douglas-fir and western redcedar with minor components of western hemlock, grand fir, and western white pine.

### **Treatment Unit 5: Group Selection**

**Management Objectives:** The system will achieve a multi-aged mosaic of even-aged groups of predominantly Douglas-fir without large and visually obtrusive harvest areas.

This treatment resembles the modified patch cuts regime, except that removals will be over a range of small groups of trees, from a minimum opening of 0.05 ha to a maximum opening of 0.5 ha. In the classic definition of this silvicultural system, "group" is defined as an opening equal to or less than two tree lengths in diameter. In this experiment, due to opening size targets, the system is defined as an opening less than two tree heights on at least one side.

The unit will be harvested over a rotation of 80 years with four separate harvesting passes. The first pass post-logging structure included 20 openings ranging in size from 0.05 to 0.5 ha (4.8 ha total). There is also 0.3 ha of corridors. Successive harvest will include patches and corridors totalling 4.8 ha for each pass. No two adjacent patches will be harvested in the same pass. Locations of harvest units and corridors for future passes have been proposed and are shown in Figure A1.12. Future planning will include an assessment of windthrow hazard for the next pass. Areas harvested, including corridors, will be regenerated to an even-aged stand of Douglas-fir and western redcedar with a minor component of western hemlock, grand fir, and western white pine. Retained timber will be representative of the original stand (western hemlock, Douglas-fir, and western redcedar with minor grand fir and western white pine) and will have elements of stand and forest structure from the pre-harvest stand, through to the next rotation, to meet biodiversity objectives. The silvicultural system will allow retention trees to provide greater than 50% influence to the harvest area throughout the unit.

For consistency, cutting entries must adhere to one of the following opening size regimes, with the goal of equal representation of each opening size over the 80 years. In the first pass, the number of harvest unit openings of each size are as follows: three 0.05 ha, five 0.1 ha, four 0.2 ha, three 0.3 ha, three 0.4 ha, and two 0.5 ha.

### **Treatment Unit 6: Modified Patch Cuts**

**Management Objectives:** The system will achieve a multi-aged mosaic of even-aged patches of predominantly Douglas-fir without large and visually obtrusive harvest areas.

The modified patch cuts treatment at STEMS incorporates two variations to the classic/legal definitions of this silvicultural system:

1. The patch cuts will not be managed as discrete openings. The intent is area regulation over the entire operational block. Over one rotation, there will be a series of entries with pre-determined opening sizes. Over time, the area will develop as a multi-aged structure, with an equal area represented in four age classes. This system, therefore, is a hybrid of the selection and patch cut systems.
2. Patch cut size will be larger than the legal definition of 1 ha or less. This was necessary to test a wider range of opening sizes.

The TU will be harvested over a rotation of 80 years with four separate harvesting passes. The first pass post-logging structure will include six openings (total of 7.2 ha) ranging in size from 0.6 to 2.0 ha. Selected trees within

the RRZ between TUs 6 and 13 will have crown modifications to reduce the risk of windthrow. Approximately 20–50 sph will be retained in the RMZ of reach 33 inside of TU 6 (Harvest Unit 13) to reduce the risk of windthrow in the adjacent RRZ. Retained timber will be crown-modified to reduce the risk of windthrow.

Successive harvest will include patches totalling 7.3 ha for each pass. No two adjacent patches will be harvested in the same pass. Locations of Harvest Units and corridors for future passes have been proposed and are shown in Figure A1.13. Future planning will include an assessment of windthrow hazard for the next pass.

Areas harvested will be regenerated to an even-aged stand of Douglas-fir and western redcedar with minor components of western hemlock, grand fir, and western white pine.

Retained timber will be representative of the original stand (Douglas-fir, western hemlock, and western redcedar with minor grand fir and western white pine) and will retain elements of stand and forest structure from the pre-harvest stand through to the next rotation, to meet biodiversity objectives. The silvicultural system will allow retention trees to provide greater than 50% influence to the harvest area throughout the unit.

Patch cut sizes: For consistency, the four cutting entries must adhere to the following opening size regime, with the goal of equal representation of each patch size over the 80-year period. In each pass the number of harvest units in openings of each size are as follows: two 0.6 ha, two 1.1 ha, and two 2.0 ha (for a total of 7.4 ha).

#### **Treatment Unit 7: Aggregate Retention**

Management Objective: To retain a component of the existing stand that, over the long term, will form a bimodal stand structure. The primary objective of the retention is enhanced visual quality and biodiversity.

The post-logging structure will include 17 aggregates (a total of 0.8 ha) of retained trees. Aggregates A–N, P, R, and S will be retained as shown in Figure A1.11. Selected aggregates (averaging approximately 70% of retained timber in the unit) will be spirally pruned to increase their windfirmness. Areas harvested will be regenerated to an even-aged stand of Douglas-fir, and western redcedar with minor components of western hemlock, grand fir, and western white pine.

The aggregates will be comprised of timber representative of the original stand (western hemlock, Douglas-fir, and western redcedar with minor components of grand fir). Aggregates will retain elements of stand and forest structure from the pre-harvest stand, for at least one rotation, to meet biodiversity objectives. Sizes of the aggregates were chosen to accommodate the Green Tree Study (described in section 8.0), which examines effects of leave trees on soil microbial and faunal communities in forest floor and mineral soils. The size and number of aggregates were as follows: five 0.002 ha, four 0.008 ha, four 0.31 ha, and five 0.125 ha. The silvicultural system will allow retention trees to provide greater than 50% influence to the harvest area throughout the unit.

Future management is to retain the aggregated leave trees for a full rotation (80 years). Trees that blow down or die will be assessed individually, but are generally not intended to be salvaged.

### 3.6 Reforestation

Artificial reforestation by planting is the strategy for all treatment units except the extended rotations with and without commercial thinning. The regeneration objective is to establish 900 sph by the regeneration date. The minimum acceptable well-spaced preferred and acceptable species is 500 sph, but with 400 sph of preferred minimum well-spaced species. All seed and vegetative material used in accomplishing this plan will be in accordance with the *Seed and Vegetative Material Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995b, Update 6). Labelled as Standards Units in the Site Plan, for the purposes of this establishment report, the terms Standards Unit and Treatment Unit are interchangeable. Species are coded as follows: Fd (Douglas-fir), Hw (western hemlock), Cw (western redcedar), Bg (grand fir), Pw (western white pine).

#### **Treatment Unit 1: Extended Rotation with Commercial Thinning**

- This is not a regeneration harvest, therefore do not plant.

#### **Treatment Unit 2: Clearcut with Reserves**

- Site series proportions: CWHxm2 05 (75%), 07 (25%), 12 (trace). Edatopic grid location: 4 (5-7)/D.
- Plant the unit in the first growing season after harvest with Fd (70%) and Cw (30%) at target stocking levels.
- Bg may make up only < 20% and Pw < 10% of the well-spaced preferred and acceptable species by sph.
- Hw is acceptable (but only in wet areas on elevated microsites) due to site series 12 components of the unit, the northerly aspect of the wetter areas, and the dominance of Hw in the existing stand. The expected species composition by sph at free growing is Fd 65%, Cw 20%, Hw 15%, Bg trace, and Pw trace.

#### **Treatment Unit 3: Extended Rotation (non-treatment control)**

- There is no harvesting in this unit, therefore do not plant.

#### **Treatment Unit 4: Uniform Dispersed Retention**

- Site series proportions: CWHxm2 07 (60%), 05 (35%), 01 (5%). Edatopic grid location: 4-5/(C-)D.
- Plant the unit in the first growing season after harvest with Fd (50%) and Cw (50%) at target stocking levels.
- Pw acceptable due to the presence of 05 site series in the unit. Pw may make up only < 10% of the well-spaced preferred and acceptable species by sph.
- Hw is acceptable due to zonal (site series 01) components of the unit, the northerly aspect in the wetter portion, and the dominance of Hw in the existing stand.
- The expected species composition at free growing is Fd 45%, Cw 40%, Hw 15%, and Pw trace.

#### **Treatment Unit 5: Group Selection**

- Site series proportions: CWHxm2 05 (75%), 07 (25%). Edatopic grid location: 4 (5)/D.
- Plant the unit in the first growing season after harvest with Fd (50%) and Cw (50%) at target stocking levels.
- Bg may make up only < 20% and Pw < 10% of well-spaced preferred and acceptable species by sph.

- The expected species composition at free growing is Fd 50%, Cw 45%, Bg 5%, and Pw (trace).

#### **Treatment Unit 6: Modified Patch Cuts**

- Site series proportions: CWHxm2 05 (80%), 07 (10%), 01 (8%), 12 (2%).  
Edatopic grid location: 4(5-7)/(C-)D.
- Plant the unit in first growing season after harvest with Fd (60%) and Cw (40%) at target stocking levels.
- Pw is acceptable due to the presence of 05 site series in the unit. Pw may make up only < 10% of the well spaced preferred and acceptable species by sph.
- Hw is acceptable due to zonal (site series 01) components of the unit, the northerly aspect in the wetter portion of the unit, and the dominance of Hw in the existing stand.
- The expected species composition at free growing is Fd 50%, Cw 40%, Hw 10%, and Pw trace.

#### **Treatment Unit 7: Aggregate Retention**

- Site series proportions: CWHxm2 05(70%), 01 (15%), 07 (10%), 12 (5%).  
Edatopic grid location: 4 (5-7)/(C-)D.
- Plant standard unit in first growing season after harvest with Fd (70%) and Cw (30%) at target stocking levels.
- Pw acceptable due to the presence of 05 site series in the unit. Pw may make up only < 10% well-spaced preferred and acceptable species by sph.
- Hw is acceptable due to zonal (site series 01) components of the unit, the northerly aspect in the wetter portion of the unit, and the dominance of Hw in the existing stand.
- The expected species composition at free growing is Fd 65%, Cw 20%, Hw 15%, Bg trace, and Pw trace.

#### **All planted Treatment Units:**

- Larger planting stock is recommended to help establish seedlings.
- Fertilize seedlings when planting lowland areas with sulphur-coated nitrogen-based fertilizer, to deter elk and deer browse.
- Target raised microsites when planting Fd and fresh to moist microsites when planting Cw. In hummocky areas, avoid saturated soils.
- Localized non-productive areas exist at a low incidence throughout wetter/richer areas of the block. Dispersed non-productive colluvium is present in upper-elevation areas of the block. Areas of colluvial rubble with shallow soil and high coarse fragments may require the use of small planting stock and may make planting difficult. Minimum inter-tree spacing may be reduced to 1.5 m to achieve stocking standards in rubbly areas and immediately adjacent to non-productive sites or very moist sites. Survey in years 2 or 3, and fill plant with Fd and/or Cw if necessary, to meet stocking standards.

### **3.7 Vegetation Management**

- Site Units 2, 4, 5, 6, 7: High to Very High brush hazard.
- Brushing may be required due to the moisture and richness of soils in some areas and the presence of deciduous tree species in the units. Red alder – shrub vegetation complexes (deciduous, salmonberry, thimbleberry, bracken fern, red elderberry, and sword fern) may develop post-harvest, but prompt planting and establishment of crop conifers is

the best strategy to mitigate the need for brushing. Red alder is present in and adjacent to this stand.

- Closely monitor the level of deciduous species. If deciduous species control is recommended in surveys, use herbicide as a ground backpack or "hack and squirt" method, or alternatively, manually brush well-spaced trees.

#### 4 HARVESTING TREATMENTS

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Harvesting operations began in January 2005 and were completed in August 2005 (Table 3). Felling was performed by hand fallers, a feller-buncher (TimberKing TK923T-4 with a Rotosaw 2022T head), and feller-processors (Timberjack 608 B and Timberjack 735, both with Waratah 620 HTH heads) (Figure 1). Loader forwarding was the primary method of extraction in all the treatments except the commercial thinning and group selection treatments, where feller processors were used to extract the logs to roadside. Processing was done by feller processors either at the stump or at roadside. A Hitachi 450 LL carrier with a Waratah 624 HTH processing head also worked at roadside (Figure 1). Loading was done by hydraulic loaders. The loader forwarders and/or loaders included a Komatsu PC 300 HD, a Hitachi EX 450 LL, a Hitachi 350 LL, and a Hitachi 300 LL (Figure 2).

A cost and productivity study was conducted by FERIC. Servis recorders were used for recording the activity of vehicles throughout a given work period, and operators recorded delays greater than 10 minutes. Scheduled machine hours (including rest breaks, repairs, and maintenance) were calculated for each machine and treatment based on operator reports and Servis recorder charts. The results of this study will be published separately.



FIGURE 1 Timberjack feller/processor (right) and Hitachi log loader/forwarder (left) at work in the clearcut with reserves treatment.





FIGURE 2 *Komatsu hydraulic loader in the uniform dispersed retention treatment.*

## 5 FOREST PRODUCTIVITY STUDY

### 5.1 Methods

**5.1.1 Sampling design** The sampling design consists of periodically remeasured fixed-area tagged tree plots located on a permanently monumented systematic grid within each treatment unit (TU). Spacing, number, and arrangement of plots depend on the area of the TU and expected post-treatment stand heterogeneity. Any wildlife reserve patches, riparian strips, major road rights-of-way, and inclusions of site or stand conditions markedly different from those on other units were excluded from the sample. Plot locations were established after major roads had been located to minimize subsequent loss of plots, but an access road in the aggregate retention treatment was added after establishment, resulting in the loss of plot 709 (Figure A1.11). As well, windthrow along the boundary between TU2 and 3 resulted in the loss of plot 302 (Figure A1.8)

Sample size was based on the expected post-treatment, not pre-treatment, stand structure condition. Treatments resulting in even-aged stand structures require fewer samples than those resulting in multiple-age structures. The objective is to achieve about equal precision in estimates of means in all treatments, combined with precision as high as can be obtained at acceptable cost. Consequently, there are 125 permanent growth and yield plots distributed across the installation as follows:

- Block 1 – Extended Rotation with Commercial Thinning: 15
- Block 2 – Clearcut with Reserves: 15
- Block 3 – Extended Rotation (non-treatment control): (reduced to 14 in 2006)
- Block 4 – Uniform Dispersed Retention: 15



- Block 5 – Group Selection: 17
- Block 6 – Modified Patch Cuts: 25
- Block 7 – Aggregate Retention: 23 (reduced to 22 in 2006)

To avoid having two or more cohorts of very different numbers and diameters in several of the treatments, the plots were designed as multiple, circular, concentric fixed-area plots (Figure 3). A single fixed-area plot would sample an adequate number of small trees but an inadequate number of large trees, or sample an adequate number of large trees but an extremely large number of small trees. The choice of a basic 0.1-ha plot is based on the expectation that we want to classify plot estimates by strata (patch vs. intervening area) in the patch and group selection treatments, which will require relatively small plots. The plot sizes, the size of tree measured in each, and the corresponding plot expansion factor are listed in Table 4.

Plots for regeneration and vegetation assessments are 3.99-m radius (0.005 ha) and are located on each cardinal point 17.8 m from the permanent plot centre.

Coarse woody debris (CWD) plots are measured by line intersect sampling (LIS) using a 75-m line transect in the shape of a spoke (3- to 25-m lines) established at the centre of each growth and yield permanent sample plot. The direction of the first 25-m transect is randomly chosen and the other two 25-m transects are established at 120° from each other.

TABLE 4 Size of circular concentric fixed-area plots, size of trees measured in each, and the corresponding plot expansion factor

Plot size (ha)	Plot radius (m)	Plot expansion factor	dbh of trees measured
0.01	5.7	100	> 4.0 cm + ingrowth
0.05	12.6	20	> 15.0 cm + ingrowth
0.10	17.8	10	> 25.0 cm + ingrowth

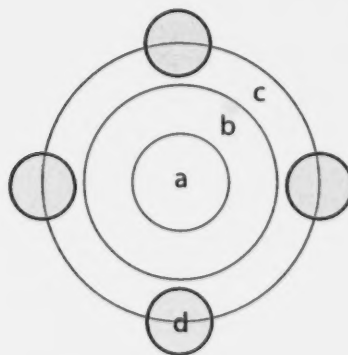


FIGURE 3 Sample plot design; (a) 0.01-ha plot to measure all trees > 4 cm or < 15 cm dbh, (b) 0.05-ha plot to measure all trees < 25 cm dbh, (c) 0.10-ha plot to measure all trees, and (d) 0.001-ha regeneration and vegetation plots located at cardinal points 17.8 m from the permanent plot centre.

**5.1.2 Plot establishment** Work began with the 1:5000 maps provided by Interfor. An accurate 60- or 70-m grid transparency was overlaid on the map, and the optimum strip-line azimuth and starting point was determined. From that starting point, the surveying commenced using a Brunton pocket transit compass on a tripod, and an Impulse Laser for measuring horizontal distance. The strips were flagged with red/white candystripe flagging tied on sticks pushed into the ground. For TUs 1–5 the plots were 60 m apart along the strips and the strips were 60 m apart. In TU 6, the plots were 70 m along strips that were 70 m apart, and in TU 7, the plots were 65 m apart along strips that were 70 m apart. Minimum distance from roads and boundaries were 48 m to the east, south, and west, and 38 m to the north of the plots. The strip-lines were carried through to the TU boundaries, and azimuth and distance to the nearest falling corner were recorded. (Note: due to the irregular shape of the northwest part of TU 4, minimum distances from the boundary had to be relaxed in order to achieve the required number of plots.)

Prospective plot locations determined in this way were marked with PVC pins. A map indicating plot locations marked with a letter code was forwarded to Research Branch staff for approval. Once final approval was given, the plots were permanently monumented with a 1-m length of rebar driven into the ground leaving only 10 cm showing; this was covered with a length of PVC painted orange and labelled with the plot number. Three reference trees were then selected and the azimuth and distance to the plot centre was recorded. This information was written on aluminum tags and stapled on the tree below stump height, facing plot centre. The area around the tag was painted orange, and vertical orange bands were painted on the outer sides of the tree. GPS co-ordinates, slope, and aspect were also recorded.

Ecosystem mapping was used to ensure that plots were distributed predominantly in site series 05 (73%), with some in representative 01 (8%) and 07 (21%) site series. Wet areas classed as 12 were avoided. The proportion of area in each site series by treatment unit is compared to the proportion of plots in Table 5.

**5.1.3 Pre-treatment measurements and assessments** Pre-treatment measurements and dates for the Forest Productivity Study at STEMS 2 included:

- Ecosystem mapping by pure site series at 1:5000 (July–August 2003).
- Measurement of all standing trees in all 0.10 ha growth and yield plots including species, dbh, tree class, and crown class (January–March 2004).
- Height and percent cover of the five most abundant shrub species within a 0.01-ha circular area (radius 5.7 m) at the plot centre of each of the 125 growth and yield plots (January–March 2004).
- Species, height, and diameter of the tallest regenerated seedling below 1.3 m in height, and sapling above 1.3 m in height within a 0.01-ha area at the plot centre in all 125 growth and yield plots (January–March 2004).
- Stump height, inside bark diameter at the top and bottom, and species of all stumps within all 0.01 ha growth and yield plots (January–March 2004).
- Plot photographs taken at the plot centre in the four cardinal directions of all 125 growth and yield plots (January–March 2004).
- Coarse woody debris measurements taken along transects measuring a total of 75 m in all growth and yield plots of TUs 1, 2, and 6 (February–March 2004).

TABLE 5 *The proportion of area in each site series by treatment unit compared to the proportion of plots in each site series*

Treatment unit	Site series	Proportion of TU area within site series (%)	Proportion of plots within site series (%)
1	01	20	10
	05	75	90
	07	5	0
	12	trace	0
2	01	0	0
	05	75	90
	07	25	10
	12	trace	0
3	01	10	10
	05	65	50
	07	25	40
	12	0	0
4	01	5	0
	05	35	40
	07	60	60
	12	0	0
5	01	0	0
	05	75	80
	07	25	20
	12	0	0
6	01	8	10
	05	80	70
	07	10	20
	12	2	0
7	01	15	5
	05	70	90
	07	10	5
	12	5	0

Appendix 2 contains detailed descriptions of the methodology for pre-treatment measurements.

**5.1.4 Post-treatment plot re-establishment** In harvested plots, if plot centres were missing, they were re-established by triangulation using a compass, a measuring tape, and the bearing and distance written on the flashing nailed to the base of the three largest trees nearest the plot centre. Often the rebar was found; but, if not, a new rebar was driven into the ground and a white PVC pipe placed overtop. At each plot centre, metal tags were attached that indicated the treatment unit and plot number. From the centre point, a compass and measuring tape were used to establish the location of the three concentric plots in the cardinal directions and distances of 5.7, 12.6, and 17.8 m. These points were flagged using metal pins with brightly coloured flags. The horizontal distances to these pins were then verified with a laser. The

centres of the vegetation/regeneration subplots (located at the cardinal directions of the 17.8-m diameter plot) were marked with white PVC hammered into the ground and labelled with metal tags. The numbering on these subplots was sequential in a clockwise direction starting from the north. The circumference of the outer plot (between the subplot markers) was then measured using a laser and flagged with tape. Trees bordering the plot were marked with a white dot if they were in. Post-treatment measurements were then taken.

**5.1.5 Post-treatment measurements and assessments** Post-treatment measurements and dates for the Forest Productivity Study at STEMS 2 included:

- Measurement of all residual standing trees in all 0.10 ha growth and yield plots including species, dbh, crown class, and tree class (July 2005).
- Harvest damage to any residual standing trees in all growth and yield plots affected by harvesting (July 2005).
- Plot photographs taken at the plot centre and facing the cardinal directions in all 125 growth and yield plots (July 2005).
- All planted trees tagged and measured within all four regeneration plots per growth and yield plot in harvested areas (September–October 2006).
- Second-year remeasurement of all tagged regeneration (August 2006).
- Natural regeneration tallied and largest naturally regenerated tree tagged and measured within all four regeneration plots per growth and yield plot in all 125 growth and yield plots (September–October 2007).
- Vegetation assessments made in all regeneration plots per growth and yield plot (August–October 2007).
- Coarse woody debris measurements taken along transects measuring a total of 75 m in all growth and yield plots of TUS 1, 2, 3, and 6 (January–March 2006).
- Soil disturbance and forest floor displacement categories recorded on Transect Survey Field Card FS 885 HSP 96/8. Soil disturbance survey summary information calculated on Small Area Survey Calculation Card FS 897 HSP 96/9. Photographs taken of representative examples of soil disturbance categories found in each stratum (February 2006).
- Windthrow surveys done to determine (a) the number, species, height, dbh, azimuth, cause, and status of windthrown trees within growth and yield plots; and (b) the extent and azimuth of windthrow patches outside of growth and yield plots and along boundaries (May 2007).
- Hemispherical photographs taken at plot centre of all 125 growth and yield plots, plus all 500 regeneration plots (July 2008).
- Increment cores taken from one randomly selected tree per plot for all plots with at least one standing tree mounted and sanded, with increments measured using Windendro (January–March 2008)

For detailed information about these post-treatment assessments and measurements, see Appendix 3.

**5.1.6 Data analysis** Data from the initial establishment and the post-treatment measurements were analyzed. Since only a small number of tree heights were measured, these data were used to develop a height-dbh model to predict the heights for the other trees for both the pre- and post-treatment

measurements. This model was based on the log-logistic function (e.g., see Monserud 1984):

$$H = 1.3 + \frac{a + u}{1 + e^{b + c \times \ln(\text{dbh})}} + \epsilon$$

where  $H$  = tree height (m),  $\text{dbh}$  = tree diameter at breast height (cm),  $a$ ,  $b$ , and  $c$  = model parameters to be estimated,  $u$  = random effect with block as the subject, and  $\epsilon$  = random error term. A separate model was fit for each measurement using procedure NLMIXED in SAS (SAS Institute Inc. 2004). The fitted models are:

$$\text{Pre-treatment model: } H = 1.3 + \frac{46.95 + u}{1 + e^{4.293 - 1.400 \times \ln(\text{dbh})}}$$

where  $u$  = -1.694 (for block 1), -1.604 (for block 2), -2.638 (for block 3), -1.394 (for block 4), -1.924 (for block 5), 3.426 (for block 6), or 5.828 (for block 7), and

$$\text{Post-treatment model: } H = 1.3 + \frac{47.84 + u}{1 + e^{4.280 - 1.418 \times \ln(\text{dbh})}}$$

where  $u$  = -0.877 (for block 1), -2.079 (for block 3), -0.346 (for block 4), -1.496 (for block 5), 3.587 (for block 6), or 1.210 (for block 7).

Total and merchantable tree volume was calculated for each tree using Kozak's (1988) taper equations to get the basal area at the top, bottom, and middle of each 1 m length of tree stem, and Simpson's rule (Burden et al. 1978) to integrate the basal areas to get the volume of each 1 m length of stem. It was assumed for the merchantable volume calculations that the stump height was 30 cm and that the merchantable inside bark top diameter was 10 cm.

## 5.2 Treatment Results

Examples of the visual differences between pre- and post-harvest stand conditions are shown in Figures 4–16, taken at the plot centres of growth and yield plots before and after treatment.

**5.2.1 Pre- and post-harvest stand statistics** Post-harvest natural regeneration beginning 60–80 years ago resulted in a stand dominated by western hemlock with a minor cover of Douglas-fir, western redcedar, and western white pine. An initial reconnaissance survey indicated only minor differences between the two treatment areas (TUS 1–5 vs TUS 6 and 7), including an age difference estimated to be between 10 and 20 years. In fact, aging by tree core sampling across the installation, we found that the average age of TUS 1–5 was about 57 years old, while age of TUS 6 and 7 was 95 years old. Consequently, stand volumes and tree sizes varied significantly between the treatment areas.

Pre-treatment differences across the installations were compared using the average of plots sampled within treatment units. Before harvest, TUS 1–5 had significantly greater live density, and trees were smaller in height, diameter, basal area, and volume than TUS 6 and 7 (Table 6).

Pre-treatment live volume by species and treatment unit is shown in Table 7. On average, western hemlock accounted for 76% of the total volume, Douglas-fir 20%, western redcedar 3%, and grand fir, red alder, and bigleaf maple less than 1% each. The proportion of western hemlock by volume ranged from 67% (TU 5) to 91% (TU 6), Douglas-fir from 5% (TU 6) to 27%

TABLE 6 Pre- and post-treatment stand characteristics by treatment unit (standing live trees only). Similar letters indicate no significant differences in pre-treatment conditions between treatment units based on plot averages.

TU	QMD (cm)		Height (m)		BA (m <sup>2</sup> )		Density (sph)		Total volume (m <sup>3</sup> )		Merchantable volume (m <sup>3</sup> )		Relative density	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	31.9 a	39.5	29.4 a	34.3	76.2 abcd	31.1	974 a	256	1004 a	432	947 a	413	13.5	4.9
2	32.5 a	0.0	29.9 a	0.0	71.8 abc	0.0	881 a	0	941 a	0	890 a	0	12.6	0.0
3	30.9 a	31.6	28.7 a	29.4	72.6 abc	73.1	1003 a	959	928 a	951	870 a	894	13.0	13.0
4	31.0 a	50.2	29.2 a	38.2	67.7 bc	6.5	924 a	33	882 a	82	830 a	79	12.2	0.9
5	32.9 a	33.1	29.8 a	30.4	68.4 c	43.1	818 a	498	889 a	564	841 a	534	11.9	7.5
6	44.0 b	44.1	37.2 b	37.0	79.8 cd	59.7	554 b	403	1297 b	976	1244 b	936	12.0	9.0
7	47.4 b	43.2	38.4 b	33.0	82.2 d	2.0	520 b	19	1405 c	31	1353 c	30	11.9	0.3

Relative Density is Curtis' RD = BA/√QMD

TABLE 7 Pre-treatment live standing volume and percent of total live standing volume by treatment unit and species

TU	Western hemlock		Douglas-fir		Western redcedar		Grand fir		Sitka spruce		Red alder	
	Volume (m <sup>3</sup> )	% of total	Volume (m <sup>3</sup> )	% of total	Volume (m <sup>3</sup> )	% of total	Volume (m <sup>3</sup> )	% of total	Volume (m <sup>3</sup> )	% of total	Volume (m <sup>3</sup> )	% of total
1	766	76.5	220	22.0	16	1.6	2	0.2	0	0.0	0	0.0
2	667	70.9	249	26.5	15	1.6	0	0.0	1	0.1	8	0.9
3	666	71.8	195	21.0	51	5.5	7	0.8	1	0.1	7	0.8
4	596	67.6	237	26.9	10	1.1	9	1.0	1	0.1	30	3.4
5	599	67.4	263	29.6	5	0.6	8	0.9	1	0.1	11	1.2
6	1180	91.0	59	4.5	55	4.2	2	0.2	0	0.0	0	0.0
7	1213	86.3	142	10.1	36	2.6	13	0.9	0	0.0	1	0.1
Mean	812	75.9	195	20.1	27	2.5	6	0.6	1	0.1	8	0.9

(TU 5), and western redcedar from 1% (TU 5) to 5% (TU 3). Grand fir was found in trace amounts in all except TU 2 and TU 6, Sitka spruce was found in trace amounts in all but TU 1, and red alder was found as high as 3% volume in TU 4 and in trace amounts in all but TU 1 and 5.

The proportion of dead standing trees relative to live in these dense stands was quite high, ranging in density from 25% in TU 7 to 38% in TU 3 and in volume by 8% in TU 1 to 32% in TU 6 (Table 8). In terms of species-specific mortality, Douglas-fir had a higher proportion of dead standing trees than western hemlock (Table 9).

The proportion of standing dead volume relative to live volume varied by species (Table 9). Standing dead volume of western hemlock ranged from 6% (TU 1) to 25% (TU 6); Douglas-fir from 12% (TU 1) to 75% (TU 6); western redcedar from 15% (TU 5) to 62% (TU 4); and grand fir from 0% (most TUs) to as high as 38% (TU 7).

A comparison of pre- and post-harvest stand statistics by treatment unit is given in Table 6. The extended rotation with commercial thinning treatment reduced pre-treatment live density (trees per ha) by 74%; the group selection and patch cut treatments by 39% and 27%, respectively; and the dispersed and aggregated retention treatments by 97% and 96%, respectively. Post-treatment volume by species (Table 10) indicates that the proportion of live standing volume by species did not change in TU 1, TU 3, TU 5, and TU 6 but that of Douglas-fir increased and western hemlock decreased relative to the pre-treatment conditions in the dispersed and aggregated retention treatments (TUs 4 and 7, respectively).

The prescription for the post-thinning density in TU 1 (extended rotation with commercial thinning), was to leave 300 crop trees but the post-thinning density was 260 sph, somewhat lower than expected. This occurred because spacing, in many cases, was 6 m rather than 5 m, to get the best crop trees.

**5.2.2 Regeneration** Cutblocks were planted in late winter 2006. The number of regeneration plots in cutblock openings, and therefore planted, varied with treatment unit; in TUs 2, 4, and 7 (clearcut with reserves, uniform dispersed retention, and aggregate retention) where the entire block was regenerated, all regeneration plots were planted. In TUs 5 (group selection) and 6 (modified patch cuts), 34 and 22% of all regeneration plots, respectively, were in cutblock openings requiring planting. Regeneration surveys were done on all regeneration plots planted in late summer of 2006.

TABLE 8 Pre-treatment proportion of dead standing trees relative to standing live trees by treatment unit

TU	Density (sph)			Total volume (m <sup>3</sup> )			Merchantable volume (m <sup>3</sup> )		
	Live and dead	Live only	Dead (%)	Live and dead	Live only	Dead (%)	Live and dead	Live only	Dead (%)
1	1432	974	32	1088	1004	8	1014	947	7
2	1317	881	33	1046	941	10	976	890	9
3	1629	1003	38	1055	928	12	972	870	10
4	1447	924	36	997	882	12	922	830	10
5	1300	818	37	982	889	9	915	841	8
6	836	554	34	1913	1297	32	1831	1244	32
7	697	520	25	1919	1405	27	1846	1353	27



TABLE 9 Pre-treatment total standing volume, live-only standing volume, and proportion of dead standing volume by species and treatment unit

TU	Western hemlock			Douglas-fir			Western redcedar			Grand fir			Sitka spruce			Red alder		
	Live and dead	Live only	Dead (%)	Live and dead	Live only	Dead (%)	Live and dead	Live only	Dead (%)	Live and dead	Live only	Dead (%)	Live and dead	Live only	Dead (%)	Live and dead	Live only	Dead (%)
1	810	766	5	250	220	12	24	16	33	2	2	0	0	0	0	1	0	100
2	716	667	7	294	249	15	26	15	42	0	0	0	1	1	0	8	8	0
3	712	666	6	256	195	24	67	51	24	7	7	0	1	1	0	12	7	42
4	635	596	16	288	237	18	27	10	63	9	9	0	1	1	0	36	30	17
5	646	599	7	303	263	13	6	5	16	8	8	0	1	1	0	15	11	27
6	1568	1180	25	234	59	75	109	55	50	2	2	0	1	0	100	0	0	0
7	1340	1213	9	475	142	70	80	36	55	21	13	38	1	0	100	2	1	50

TABLE 10 Post-treatment live volume and percent of total treatment unit live volume by species and treatment unit

TU	Western hemlock		Douglas-fir		Western redcedar		Grand fir		Sitka spruce		Red alder	
	m <sup>3</sup>	%	m <sup>3</sup>	%	m <sup>3</sup>	%	m <sup>3</sup>	%	m <sup>3</sup>	%	m <sup>3</sup>	%
1	320	74.0	108	25.0	5	1.2	0	0.0	0	0.0	0	0.0
2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	684	71.9	200	21.0	51	5.4	7	0.7	1	0.1	7	0.7
4	2	2.4	79	96.7	0	0.0	0	0.0	0	0.0	0	0.0
5	371	65.8	177	31.4	4	0.7	7	1.2	1	0.2	4	0.7
6	889	91.1	32	3.3	53	5.4	2	0.2	0	0.0	0	0.0
7	25	80.6	6	19.4	1	3.2	0	0.0	0	0.0	0	0.0

The regeneration target was 900 sph but, as indicated in Table 11, after the first year, density was about 800 sph in TUs 4 and 5. Mortality in the first year was found only in the clearcut and was less than 1%. TUs 2, 3, 5, and 7 were fill-planted in late winter of 2007 and regeneration surveys in July 2007 indicated that 1–3% of total seedlings had been replanted. Mortality after 2 years was highest in the patch cut treatment (6%) and ranged from 1 to 3% in all other TUs. Browsing on live planted seedlings was noted in the second-year survey, with TU averages ranging from 8 to 19% of seedlings per hectare browsed. However, western redcedar seedlings were more intensively browsed than Douglas-fir, with 21–30% of planted seedlings browsed vs 1–7% of Douglas-fir (Table 11).

The second summer after harvest, natural regeneration density averaged between 300 and 400 sph in planted plots.

**5.2.3 Vegetation** A summary of the percentage cover on vegetation plots surveyed the second summer after harvest is shown in Table 12. There were no undisturbed plots on TUs 1, 2, 4, and 7 (extended rotation with commercial thinning, clearcut with reserves, uniform dispersed retention, and aggregate retention) and there were no disturbed plots on TU 3 (extended rotation). Vegetation layers are classified according to height and vegetation: layers A, B<sub>1</sub>, and B<sub>2</sub> consist of all trees and shrubs > 10 m, 2–10 m, and < 2 m, respectively; layer C consists of herbs; and layer D consists of bryoids. In general, canopy cover from the A layer was highest in undisturbed plots (65–78%) but averaged 31% in the commercial thinning treatment and 4% in the dispersed retention. Trees in the B<sub>1</sub> and B<sub>2</sub> layers and shrubs in the B<sub>1</sub> layer averaged less than 1% in both disturbed and undisturbed plots.

Shrubs in the B<sub>2</sub> layer and herbs tended to be more abundant in disturbed plots of TUs 2, 4, and 7 but still averaged less than 5% cover. The sparsity of understorey vegetation in both disturbed and undisturbed plots is evident in the pre- and post-treatment examples (Figures 4–16).

The most common herb and shrub species across the entire installation were *Vaccinium parvifolium*, *Rubus* spp. (*leucodermis*, *parviflorus*, *spectabilis*), *Carex* spp., and ferns *Pteridium aquilinum*, *Polystichum munitum*, and *Blechnum spicant* (Table 13).

**5.2.4 Coarse woody debris** Pre-treatment coarse woody debris (CWD) was sampled using line transect plots in TUs 1, 2, and 6 (extended rotation with

TABLE 11 Regeneration survey results in planted plots one and two growing seasons after harvest by treatment unit

TU	1st-year survey results					2nd-year survey results						
	Total number of regeneration plots	Total number of regeneration plots planted	Proportion of all regeneration plots planted (%)	Live planted seedlings (sph)	Mortality (%)	Total live planted seedlings (sph)	Proportion of seedlings replanted (%)	Proportion of seedlings browsed (%)	Proportion of seedlings browsed by species (%)		Mortality (%)	Natural regeneration (sph)
									Fd	Cw		
2	60	60	100	937	1	943	1	14	7	30	2	323
4	60	60	100	800	0	820	2	8	1	24	1	373
5	68	23	34	809	0	826	2	19	5	26	6	383
6	100	22	22	918	0	918	0	13	4	21	2	391
7	88	88	100	882	0	911	3	13	7	23	3	327

TABLE 12 Vegetation cover (%) by layer, treatment unit, and disturbance class

Vegetation cover (%)															
Layer	Grouping	TU 1		TU 2		TU 3		TU 4		TU 5		TU 6		TU 7	
		Dis (N=60)	Undis (N=0)	Dis (N=60)	Undis (N=0)	Dis (N=0)	Undis (N=60)	Dis (N=60)	Undis (N=0)	Dis (N=32)	Undis (N=36)	Dis (N=35)	Undis (N=65)	Dis (N=91)	Undis (N=0)
A	Trees	31.42	N/A	0.08	N/A	N/A	65.57	4.27	N/A	20.80	76.97	11.66	77.98	0.90	N/A
		2.30		0.08			2.40	1.04		4.75	0.87	3.06	0.72	0.57	
B1	Trees	0.03	N/A	0.00	N/A	N/A	0.37	0.15	N/A	0.05	0.13	0.00	0.01	0.00	N/A
		0.02		0.00			0.18	0.15		0.03	0.05	0.00	0.01	0.00	
B1	Shrubs	0.00	N/A	0.00	N/A	N/A	0.00	0.00	N/A	0.00	0.00	0.02	0.04	0.04	N/A
		0.00		0.00			0.00	0.00		0.00	0.00	0.01	0.01	0.03	
B2	Trees	0.84	N/A	0.47	N/A	N/A	0.26	0.67	N/A	0.66	0.17	1.47	1.06	1.38	N/A
		0.08		0.04			0.08	0.04		0.11	0.02	0.36	0.21	0.15	
B2	Shrubs	0.47	N/A	4.88	N/A	N/A	0.15	2.96	N/A	2.40	0.23	0.56	0.39	2.85	N/A
		0.07		0.46			0.03	0.28		0.50	0.04	0.05	0.03	0.23	
C	Herbs	1.27	N/A	5.93	N/A	N/A	0.79	2.43	N/A	2.48	0.99	1.81	3.41	5.00	N/A
		0.22		0.52			0.17	0.25		0.45	0.23	0.68	0.57	0.48	
D	Bryoids	0.37	N/A	0.09	N/A	N/A	1.88	0.12	N/A	1.16	1.74	0.76	2.04	0.36	N/A
		0.08		0.04			0.21	0.03		0.30	0.20	0.17	0.20	0.11	
Slash	Debris	18.86	N/A	12.08	N/A	N/A	9.06	24.92	N/A	19.36	15.28	19.73	9.08	19.00	N/A
		0.97		1.09			1.09	1.91		1.61	1.99	2.13	0.59	0.84	
All	All	46.54	N/A	22.63	N/A	N/A	70.37	33.82	N/A	42.50	81.21	34.03	83.73	29.05	N/A
		2.07		1.19			2.21	2.05		3.60	0.98	3.74	0.63	1.20	

TABLE 13 *Most common shrub and herb species present (%) on disturbed and undisturbed plots by treatment unit and layer. (Species codes are listed in Appendix 4.)*

<b>B2 Layer: Undisturbed</b>									
TU	BLECSPI	GAULSHA	POLYMUN	PRUNEMA	RUBUPAR	RUBUSPE	VACCMEM	VACCOVA	VACCPAR
3	0.003	0.007	0.027			0.003		0.012	0.102
5		0.008		0.008	0.014	0.019			0.175
6		0.022		0.002		0.005	0.003		0.357
<b>B2 Layer: Disturbed</b>									
TU	GAULSHA	GRAMIN	PRUNEMA	RUBULEU	RUBUPAR	RUBUSPE	RUBUSURS	SAMBRAS	VACCPAR
1	0.018		0.053	0.037	0.018	0.205	0.017		0.102
2		0.133		1.038	0.835	2.475	0.107		
4				0.388	0.320	1.763	0.193		0.113
5	0.022		0.025	0.334	1.047	0.797		0.022	0.150
6	0.020		0.034	0.034	0.023	0.146		0.083	
7				0.367	0.211	0.982		0.491	0.451
<b>C Layer: Undisturbed</b>									
TU	ATHYFIL	BLECSPI	DRYOEXP	GOODOBL	GRAMIN	GYMNDRY	POLYMUN	PTERAQU	TIARTRI
3		0.200	0.007			0.025	0.563	0.007	0.017
5		0.492	0.011	0.008	0.022		0.417	0.119	
6	0.009	2.829	0.008				0.532		
<b>C Layer: Disturbed</b>									
TU	ATHYFIL	BLECSPI	CAREX sp.	DICEFOR	EPILANG	GRAMIN	POLYMUN	PTERAQU	SENESYL
1		0.288	0.158			0.307	0.322	0.180	
2		0.380	1.298	0.702		1.973	0.425	1.095	0.432
4		0.275	0.773			0.380	0.507	0.325	
5		0.831	0.147			0.344	0.300	0.844	
6	0.020	1.117	0.051		0.091	0.029	0.474		
7		3.025	0.159		0.263	0.371	0.935		

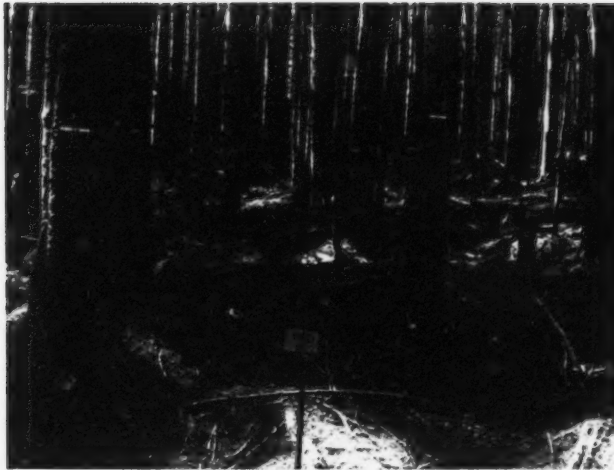


FIGURE 4 *View of plot 103 looking south in the extended rotation with commercial thinning treatment before harvest.*



FIGURE 5 *View of plot 103 looking south in the extended rotation with commercial thinning treatment immediately after harvest.*



**FIGURE 6** *View of plot 215 looking east in the clearcut with reserves treatment before harvest.*



**FIGURE 7** *View of plot 215 looking east in the clearcut with reserves treatment immediately after harvest. Note the debris piles.*



FIGURE 8 *View of plot 402 facing west in the uniform dispersed retention treatment before harvest.*



FIGURE 9 *View of plot 402 facing west in the uniform dispersed retention treatment immediately after harvest.*





FIGURE 10 *View of plot 507 facing south in the group selection treatment before harvest.*



FIGURE 11 *View of plot 507 facing south in the group selection treatment immediately after harvest.*



FIGURE 12 *View of plot 604 facing west in the modified patch cuts treatment before harvest.*



FIGURE 13 *View of plot 604 facing west in the modified patch cuts treatment immediately after harvest.*



FIGURE 14 *View of plot 701 facing east in the aggregate retention treatment before harvest.*



FIGURE 15 *View of plot 701 facing east in the aggregate retention treatment immediately after harvest.*



FIGURE 16 View of plot 312 looking south in the extended rotation (non-treatment control) treatment. Note the large burned stump on the left, the old-growth logging debris in the foreground, and the more recently deposited material originating from the second-growth forest.



FIGURE 17 Sampling coarse woody debris along transects.

commercial thinning, clearcut with reserves, and modified path cuts treatments, respectively) (Figure 17). All three treatment units sampled had a previous logging history and many of the larger ecological class 4 and 5 pieces appear to be old logging debris originating from the 1920s, with some pieces showing evidence of old cuts and breaks (Figures 4, 12, and 14). Most pieces sampled were small- to medium-sized pieces originating from intermediate stems dying out due to self thinning in the stand (Figures 6, 8, and 16). The amount of coarse woody debris in TUS 1–3 was somewhat variable but that in TU 6 was much higher, likely due to the older age and size of the stand (Table 14).

Post-treatment coarse woody debris volume included both the transect surveys and estimates of pile volumes (Figures 17 and 18). In addition to the old-growth logging debris and recently deposited material originating from the second-growth forest, most pieces tallied were identified as class 1 from recent logging (Figures 5, 7, 9, 11, 13, and 15). The number of piles after harvest was quite high, with 183 on the clearcut (11.9 harvested ha) and 69 on the patch cut (7.2 harvested ha). These piles added significantly to the overall volume of CWD on harvested areas and represented a total pile area of 5060 m<sup>2</sup> (0.51 ha) (Figures 7, 9 and 13).

TABLE 14 Coarse woody debris estimates by treatment unit. Pile survey and total CWD volume are post-treatment.

Treatment unit	Transect survey (m <sup>3</sup> /ha)		Pile survey				Total CWD volume (m <sup>3</sup> /ha)
	Pre	Post	Number of piles	Mean area of piles (m <sup>2</sup> )	Mean volume per pile (m <sup>3</sup> /ha)	Total volume of all piles (m <sup>3</sup> /ha)	
1	231.78	123.64					123.64
2	204.61	117.35	183	609	12.95	2369.85	2487.20
3		291.03					291.03
6	410.73	422.04	69	351	19.17	1322.73	1744.77

TABLE 15 Soil disturbance by treatment unit

TU	Site series	Net harvested area (ha)	Maximum allowable soil disturbance area (%)	Counted soil disturbance (mean %)	Counted soil disturbance (LCL %)	Counted forest floor disturbance (mean %)	Counted forest floor disturbance (LCL %)
1	05750120075	15.0	5	2.9	1.4	5.1	3.2
2	05750125	11.9	5	2.2	1	5.4	3.6
4	07600535015	9.8	5	1.4	0.5	3.4	2.1
5	05750125	5.1	5	1.4	0.1	5	2.9
6	05800710018122	7.2	5	2.4	1	3.6	1.9
7	057001150710125	23.7	5	0.8	0	1.9	0.7



FIGURE 18 Sampling coarse woody debris in piles.

**5.2.5 Soil disturbance** The soil disturbance survey was conducted in February 2006 after harvest. Levels of soil disturbance for each treatment (Table 15) were well below allowable maximums for each TU. The lowest levels of mean soil disturbance (0.8%) occurred in the aggregate retention treatment, and the greatest (2.9%) occurred in the commercial thinning treatment. Evidence of machine tracks was noticeable throughout, but the ruts were often too short to be countable (Figure 19). Some scalping occurred, possibly in conjunction with the rehabilitation of the main access routes (Figure 20). Access trails to the patch cut and group selection openings were all rehabilitated by fluffing the compacted portions in the ruts and distributing organic material onto the trails (Figure 21).

**5.2.6 Harvesting damage to residual standing trees** Tree damage (Table 16) was high in the commercial thinning, dispersed retention, and aggregate retention treatment units, with 61, 58, and 50% of total retained trees, respectively, showing damage. The damage was primarily from yarding in the commercial thinning treatment, and from falling in the retention treatments. Damage was mostly near the base of standing trees. The proportion of standing trees with damage at STEMS 2 is higher than at STEMS 1, but this is likely because western hemlock is thin-barked and more susceptible to damage than Douglas-fir (Figure 22).

**5.2.7 Windthrow** Within-plot windthrow losses were highest in both retention treatments despite the mitigation treatments. Only 46 and 76% of the residual trees were still standing and straight after 2 years in the aggregated and dispersed retention treatments, respectively (Table 17). Surveys of windthrow at block boundaries indicated that windthrow occurred to some degree at all cutblock edges. Plot 302 and 303 in the extended rotation, and plot 609 in the modified patch cut treatments, have been impacted by windthrow. Windthrow losses will continue to be monitored and the data used for windthrow model calibration/validations (Figure 23).

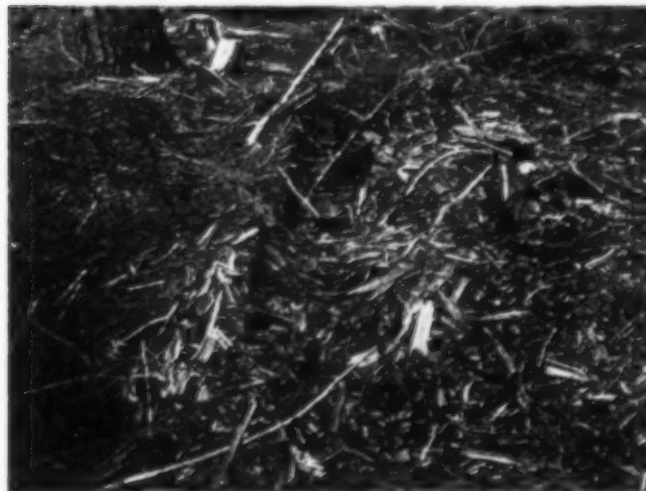


FIGURE 19 Evidence of machine tracks was noticeable throughout, but the ruts were often too short to be countable. (Image from Econ Consulting.)

TABLE 16 Incidence of tree damage by treatment unit

TU	Treatment description	Trees sampled	Damage classification		Distribution of damage by depth class							Distribution of damage by cause				
			Trees with damage (all depths) (%)	Trees with phloem exposed or gouged (damage > B class) (%)	Mean scar area (cm <sup>2</sup> )	Mean scar ht above ground (cm)	Class A (surface bruised and phloem not exposed) (%)	Class B (phloem exposed) (%)	Class C (wood gouged <1 cm deep) (%)	Class D (wood gouged >1 cm deep) (%)	Class Eg (tree stem damaged at ground) (%)	Falling (%)	Falling and/or yarding (%)	Yarding (%)	Windfall (%)	Unknown (%)
1	Extended Rotation with Commercial Thinning	362	61.4	55.7	691	51.3	9	67	6	16	2	22	0	73	3	2
2	Clearcut with Reserves	1371	0.0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0
3	Extended Rotation (non-treatment control)	1077	0.1	0.1	300	175.0	0	100	0	0	0	0	0	0	100	0
4	Uniform Dispersed Retention	48	58.3	56.3	1763	75.2	4	39	43	14	0	68	7	25	0	0
5	Group Selection	674	7.3	7.3	1057	44.7	0	56	34	10	0	52	19	26	3	0
6	Modified Patch Cuts	882	1.6	1.5	720	181.9	6	69	25	0	0	75	0	0	25	0
7	Aggregate Retention	24	50.0	50.0	750	36.4	0	100	0	0	0	91	0	0	9	0





**FIGURE 20** *Some scalping occurred, possibly in conjunction with the rehabilitation of the main access routes. (Image from Econ Consulting.)*



**FIGURE 21** *Access trails to the modified patch cuts and group selection openings were all rehabilitated by fluffing the compacted portions in the ruts and distributing organic material onto the trails. (Image from Econ Consulting.)*



FIGURE 22 *Example of harvest damage to residual trees in the extended rotation with commercial thinning treatment. (Image from Econ Consulting.)*



FIGURE 23 *Tree damage from windthrow in the extended rotation with commercial thinning treatment.*

TABLE 17 Percentage of residual trees standing, broken, uprooted, or leaning after 2 years by treatment unit

TU	Treatment description	Tree condition			
		Standing	Broken	Uprooted	Leaning
1	Extended Rotation with Commercial Thinning	81.7	4.8	10.4	3.0
3	Extended Rotation (non-treatment control)	93.0	1.2	4.1	1.8
4	Uniform Dispersed Retention	75.5	2.0	22.4	0.0
5	Group Selection	94.8	2.1	1.5	1.6
6	Modified Patch Cuts	94.3	1.4	2.1	2.1
7	Aggregate Retention	45.8	8.3	45.8	0.0

## 6 LIGHT STUDY

A light study titled "Light as a factor in the growth and survival of four planted coniferous species across forest gaps" has been established within the STEMS installation through funding as project number Y07-1038 provided by the Forest Investment Account – Forest Science Program. A brief description of the methodology of this study (Fielder 2005) is reported here to document its establishment at STEMS 2, but results are not included in this document.

The project will evaluate the effect of the residual stand edge on light availability and the resultant edge effects on the growth and development of planted seedlings across two forest gaps located within the STEMS experiment. The objectives of this project are to obtain data on seedling growth in response to available light for the calibration and validation of new growth and yield models for complex stands that incorporate a light model (in particular for TASS III). The data will aid in validating and checking growth and light predictions and estimates used by TRAYci, the light model integrated into TASS III.

The light study was established in a gap created within TU 5 (the group selection treatment) and is a replicate to the study site previously established at STEMS 1. The gap at STEMS 2 is roughly rectangular and about 0.41 ha, with a residual stand height of 35 m, an aspect of 25°, and a roughly 20% slope, and was selected to have approximately the same orientation (25°) as the gap in STEMS 1 (32°) and to be mid-way between a gap of 1 ha and 0.1 ha. The light environment in a gap of 0.1 ha or less (less than one tree length) is similar to a forest regime, whereas in a 1-ha gap (more than four tree lengths), more than 75% of the area has a light regime similar to that above the canopy.

In 2006, seedlings were planted in the STEMS 2 gap using a similar design to that used at STEMS 1. The planting design consists of six replicate groups of the four species arranged east/west across the block for a total of 24 rows and approximately 1800 seedlings (Figure 24). This arrangement was adopted to minimize the confounding effect of any east/west moisture gradients. Four coniferous species were selected to represent a range of shade tolerances: Douglas-fir, western hemlock, western redcedar, and western white pine. Seedlings were planted in a grid oriented more or less in the four cardinal directions with the north-south direction on a bearing of 25/205°. Planting spacing was a uniform 3 m in the east-west direction but varied between 1 and 3 m for the north-south rows. Spacing was 1 m in the gap and 10 m into the forest on the north and south edges and every 3 m thereafter. The north-



FIGURE 24 View of the light study in gap HU10 in the aggregate retention treatment.

south planting density was increased to capture the rapid change in light level close to the edge of the residual stand. Eventually the density will be reduced to 3 m in both directions.

Each seedling within the gap was measured immediately after planting and will be measured every fall after growth is complete. Measurements of height (also stem length for western hemlock), ground-line diameter, crown height, and crown diameter will be made, and a number of condition and damage codes recorded. For the purposes of light and growth simulation, every alternate planted seedling row, and all living residual stand trees within one to two tree lengths of the gap edge, were mapped. Also, the height, diameter, and canopy height of all mapped residual stems was measured.

A mast has been installed for the collection of above-canopy light data. Light data are collected using a combination of quantum sensors (LI-190SA) (LI-COR Inc., Lincoln, Nebr.) and gallium arsenide phosphide photovoltaic cells, and hemispherical canopy photographs (fish-eye photos) using a Nikon Cool-pix 5400 with a 190° field of view. Fish-eye photos were taken at 1.5 m over every seedling, as soon as possible after planting to build a light grid over the planted area of the gap. An array of 13 quantum sensors was installed north-south across the second gap in order to collect data to calibrate the fish-eye photos. The corrected light measurements will be expressed as seasonal PACL (Percent of Above Canopy Light) and as PPFD (Photosynthetic Photon Flux Density).

Microclimate measurement began in 2006, when a matrix of gypsum moisture blocks was installed across the gap. These data will be used to characterize the moisture gradients at the north and south edges. Three gypsum blocks were installed at each north-south location 1 m apart at points 3, 6, 12,

and 21 m into the gap and into the forest from each north and south edge. A total of 57 moisture blocks were installed. The moisture blocks will indicate when soils dry to potentials known to affect seedling growth. Air temperature and rainfall are being measured at one location in the centre of the block. In the winter of 2008, temperature sensors were installed north-south across the gaps at the same 12 locations as the gypsum blocks with one relative humidity sensor at the centre. Variation in vapour pressure deficit across the gap calculated from relative humidity and temperature may explain some of the variation in growth response not explained by light or by soil water potential.

## **7 GREEN TREE STUDY**

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A study titled "Green tree retention: A tool to maintain soil function after harvest" has been established within the STEMS installation. A brief description of the methodology of this study (Grayston et al. 2005) is reported here to document its establishment at STEMS 2, but interim results are not included.

There are three main questions of interest:

1. Do patches of "green tree retention" (GTR) retain the structure and function of soil biota of the uncut forest?
2. Is there a minimum retention patch size of GTR necessary to do this?
3. How far does the effect of a GTR patch extend into the harvested area and does the "shadow" vary with GTR patch size?

### **Specific objectives**

1. Determine microbial and faunal community structure and function at STEMS 2 pre-harvest (fall 2004).
2. Determine litter returns to soil and soil nutrient status in STEMS 3 pre-harvest (fall 2004).
3. Determine the effects of green tree retention patch size, density, and spatial distribution on the diversity, size, and functioning of the soil microbial and invertebrate communities post-harvest (fall 2005).
4. Determine the effects of green tree retention patch size, density, and spatial distribution on litter returns to soil and soil nutrient status (fall 2005).
5. Assess links between microbial and invertebrate structure and function (2005).

Aggregate retention patch sizes were chosen specifically to accommodate this project and varied from 5, 10, 20, and 40 m in diameter.

Pre- and post-harvest data on soil microbial and faunal communities and nutrient cycling processes were collected. In year 1 before harvest, we sampled at the centre of (what would be) each of four replicates of the four different-size aggregates, at the edge of each aggregate and then 30 m out from what will be the aggregate edge into the clearcut. This was to determine any pre-harvest spatial variability in soil organisms, which may confound our post-harvest analyses. We characterized microbial and faunal communities in

the forest floor and mineral soil of this even-aged (60–70 year) stand of western hemlock and Douglas-fir. The diversity of ectomycorrhizal fungi was assessed using morphological and molecular methods. The diversity of the soil micro-organisms was assessed using molecular fingerprinting techniques (denaturing gradient gel electrophoresis). Catabolic fingerprinting and enzyme profiling were used to assess microbial functioning. Catabolic fingerprinting measures CO<sub>2</sub> release before and after addition of a variety of substrates, which indicates the size of the microbial biomass and provides a community-level physiological profile. Enzyme profiling enables characterization of the actual functional diversity of the soil microbial community in terms of decomposition and nutrient cycling processes as the enzymes are involved in cycling of carbon, nitrogen, and phosphorus. Soil mesofauna (mites, collembolan, nematodes) were extracted from the soil using standard wet and dry extraction techniques, and identified to species or morphospecies. The abundance and community structure of the soil macrofauna (worms, millipedes, centipedes) were determined using Tullgren funnels and hand sorting. Nutrient availability in the field was determined close to each sampling point along the transect, using ion-exchange membranes (PRS probes) for both anions and cations.

In November 2005 we sampled the STEMS 2 site post-harvest for soil microbial and faunal communities. We took the post-harvest samples in November to minimize any temporal effect of sampling because we took the pre-harvest samples in November 2004. We sampled the centre and edge of each aggregate retention and then along a transect from the retention edge going 30 m out from the retention edge into the opening (taking samples at 5, 10, 15, 20, and 30 m from each aggregate retention edge; data from other trials indicate that most changes take place within 10–15 m of the edge). In the final year of the project we sampled at STEMS 1, which was then 5 years post-harvest. This allowed us to compare the longer-term effect of variable retention harvesting on soil diversity and function and also to address which spatial arrangement of green trees best preserves soil health—uniform dispersed retention, or aggregate retention.

For more information about the Green Tree Study, and to obtain some preliminary results, please refer to Grayston et al. (2005, 2006) and Bengtson et al. (2007).

## 8 LITERATURE CITED

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- Bengtson P., N. Basiliko, C.E. Prescott, and S.J. Grayston. 2007. Spatial dependency of soil nutrient availability and microbial properties in a mixed forest of *Tsuga heterophylla* and *Pseudotsuga menziesii*, in coastal British Columbia, Canada. *Soil Biology & Biochemistry* 39: 2429–2435.
- British Columbia Ministry of Forests. 2001. Visual Impact assessment guidebook. Forest Practices Code of British Columbia. Victoria, B.C. [www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/visual/Httoc.htm](http://www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/visual/Httoc.htm)
- \_\_\_\_\_. 2002. Stocking and free growing survey procedures manual, May 2002. For. Practices Br., Victoria, B.C. [www.for.gov.bc.ca/hfp/publications/00099/surveys/SurveysProcManual3.pdf](http://www.for.gov.bc.ca/hfp/publications/00099/surveys/SurveysProcManual3.pdf)



- British Columbia Ministry of Forests and British Columbia Ministry of Environment, Land and Parks. 1995a. Riparian Management Area Guidebook. Forest Practices Code of British Columbia. Victoria, B.C. [www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/Ripar2.htm#link42](http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/Ripar2.htm#link42)
- \_\_\_\_\_. 1995b. Seed and vegetative material guidebook. Forest Practices Code of British Columbia. Victoria, B.C. [www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/veg/seedtoc.htm](http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/veg/seedtoc.htm)
- \_\_\_\_\_. 1997. Soil conservation surveys guidebook. Forest Practices Code of British Columbia. Victoria, B.C.
- British Columbia Ministry of Sustainable Resource Management. 2003. Sayward Landscape Unit Plan. February 27, 2003. Victoria, B.C. [ilmbwww.gov.bc.ca/slrp/srmp/coast/campbell\\_river/sayward.htm](http://ilmbwww.gov.bc.ca/slrp/srmp/coast/campbell_river/sayward.htm)
- Burden, R.L., J.D. Faires, and A.C. Reynolds. 1978. Numerical analysis. Prindle, Weber & Schmidt, Inc. Boston, Mass.
- Curtis, R.O., D. Marshall, and D.S. DeBell. 2004. Silvicultural options of young-growth Douglas-fir forests: The Capitol Forest Study – establishment and first results. USDA. For. Serv., Pac. Northwest Res. Sta., Portland, Oreg. Gen. Tech. Rep. GTR-598.
- de Montigny, L.E. 2004. Silviculture treatments for ecosystem management in the Sayward (STEMS) : Establishment report for STEMS 1, Snowden Demonstration Forest. B.C. Min. For., Res. Br., Victoria, B.C. Tech. Rep. 017. [www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tro17.htm](http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tro17.htm)
- Fielder, P. 2005. Light as a factor in the growth and survival of four planted conifer species across forest gaps. B.C. Min. For. Victoria, B.C. Forest Investment Account – Forest Science Program Project Y071038. [www.for.gov.bc.ca/hfd/library/FIA/2007/FSP\\_Y071038a.pdf](http://www.for.gov.bc.ca/hfd/library/FIA/2007/FSP_Y071038a.pdf)
- Grayston, S.J., J.A. Addison, S.M. Berch, L. de Montigny, D.M. Durall, K.N. Egger, M.D. Jones, R. Modesto, W.W. Mohn, T.S. Panesar, C.E. Prescott, S.W. Simard, and D.S. Srivastava. 2005. Potential of green tree retention as a tool to maintain soil function after harvest. In: Balancing ecosystem values: innovative experiments for sustainable forestry. C.E. Peterson and D.A. Maguire (editors) Conf. Proc. Portland, Oreg.: USDA For. Serv., Pac. Northwest Res. Sta., Portland, Oreg. Gen. Tech. Rep. PNW-GTR-635, pp. 353–355.
- Grayston, S.J., J.A. Addison, S.M. Berch, L. de Montigny, D.M. Durall, K.N. Egger, M.D. Jones, R. Modesto, W.W. Mohn, T.S. Panesar, C.E. Prescott, and D.S. Srivastava. 2006. Green tree retention: A tool to maintain soil function after harvest. B.C. J. Ecosystems Manag. 7: 9–12.
- Grayston, S.J., N. Basiliko, N. Berg, S. Daradick, K. Del Bel, N. Piggott, C.E. Prescott, J.A. Addison, T. Panesar, S.M. Berch, L. de Montigny, D.M. Durall, Z. Lindo, B.W. Mohn and D.S. Srivastava. [2008]. Microbial and faunal communities in forest floor and mineral soils in a coastal forest of British Columbia. Can. J. For. Res. In press.



- Green, R.N. and K. Klinka. 1994. A field guide to site identification and interpretation for the Vancouver Forest Region. B.C. Min. For., Victoria, B.C. Land Manag. Handb. 28. [www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh28.htm](http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh28.htm)
- Interfor. 2004. Stream classification report. July 21, 2004. International Forest Products. Campbell River, B.C.
- Kozak, A. 1988. A variable-exponent taper equation. *Can. J. For. Res.* 18:1363–1368.
- Marshall, P.L. and G. Davis. 2002. Measuring the length of coarse woody debris. B.C. Min. For., Res. Section, Vancouver Forest Region, Nanaimo, B.C. For. Res. Exten. Note 11.
- Marshall, P.L., G. Davis, and V.M. LeMay. 2000. Using line intersect sampling for coarse woody debris. B.C. Min. For., Res. Section, Vancouver Forest Region, Nanaimo, B.C. Tech. Rep. TR-003.
- Meidinger, D. 1998. Field manual for describing terrestrial ecosystems. B.C. Min. Env., Lands and Parks and B.C. Min. For., Victoria, B.C. Land Manag. Handb. 25. [www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh25.htm](http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh25.htm)
- Mitchell, S. 2004. Windthrow prediction for STEMS 2. Study area report. Dec. 10, 2004. International Forest Products, Campbell River, B.C.
- Monserud, R.A. 1984. Height growth and site index curves for inland Douglas-fir based on stem analysis data and forest habitat type. *For. Sci.* 30:943–965.
- Resources Information Standards Committee. 2008. Vegetation resources inventory ground sampling procedures. B.C. Min. For. Range, For. Analysis and Inventory Br. for the Terrestrial Ecosystems Task Force, Resources Information Standards Committee, Victoria, B.C. [ilmbwww.gov.bc.ca/risc/pubs/teveg/vri\\_gs\\_2k8/vri\\_gs\\_4.8.pdf](http://ilmbwww.gov.bc.ca/risc/pubs/teveg/vri_gs_2k8/vri_gs_4.8.pdf)
- SAS Institute Inc. 2004. SAS OnlineDoc® 9.1.3. SAS Institute Inc., Cary, N.C.
- Swanson, J. 2005. Site plan for Forest Licence A19232, Cutting Permit 96. STEMS 2 at Elk Bay. International Forest Products. Jan. 17, 2007.

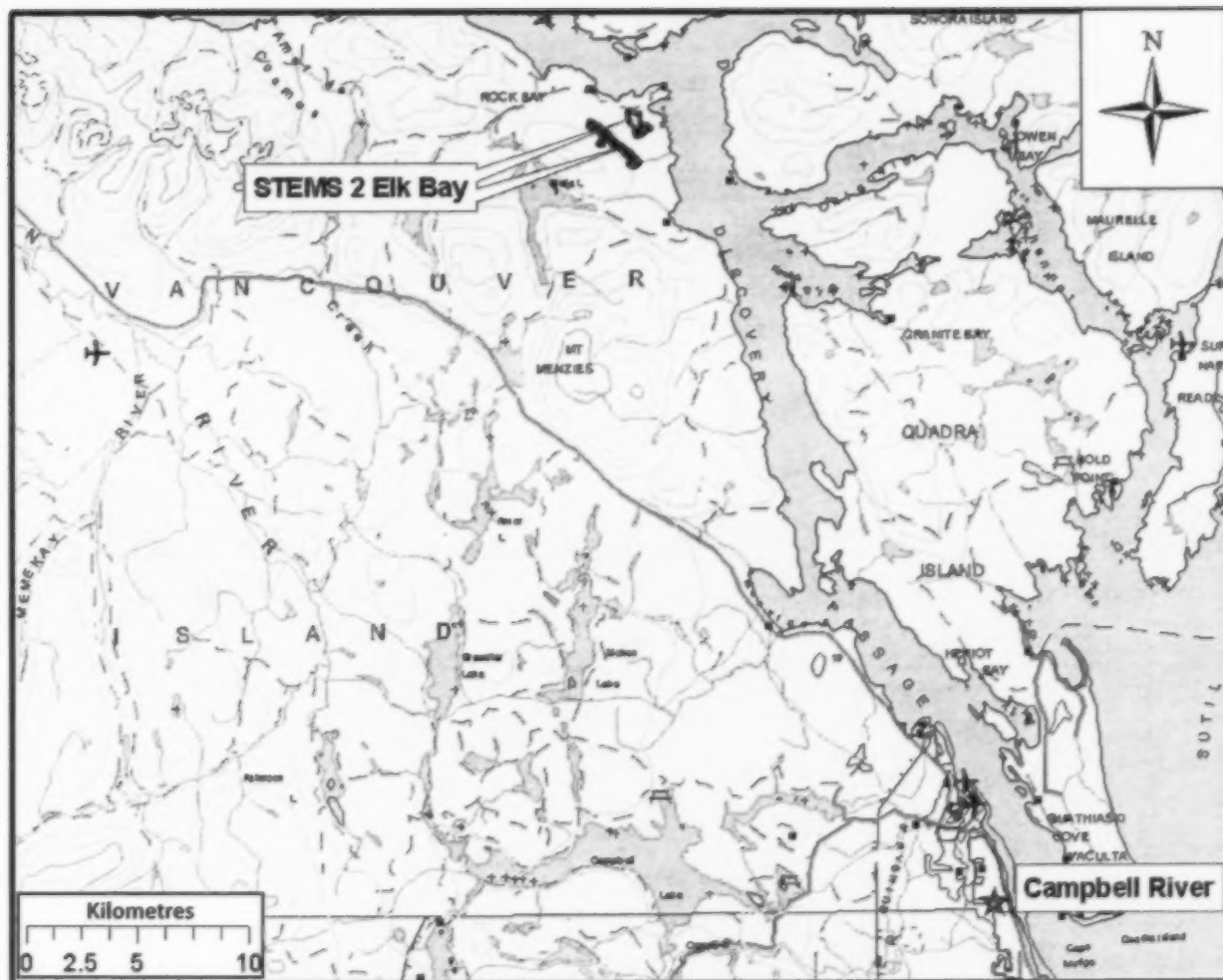


FIGURE A1.1 Location of the STEMS 2 experimental site.



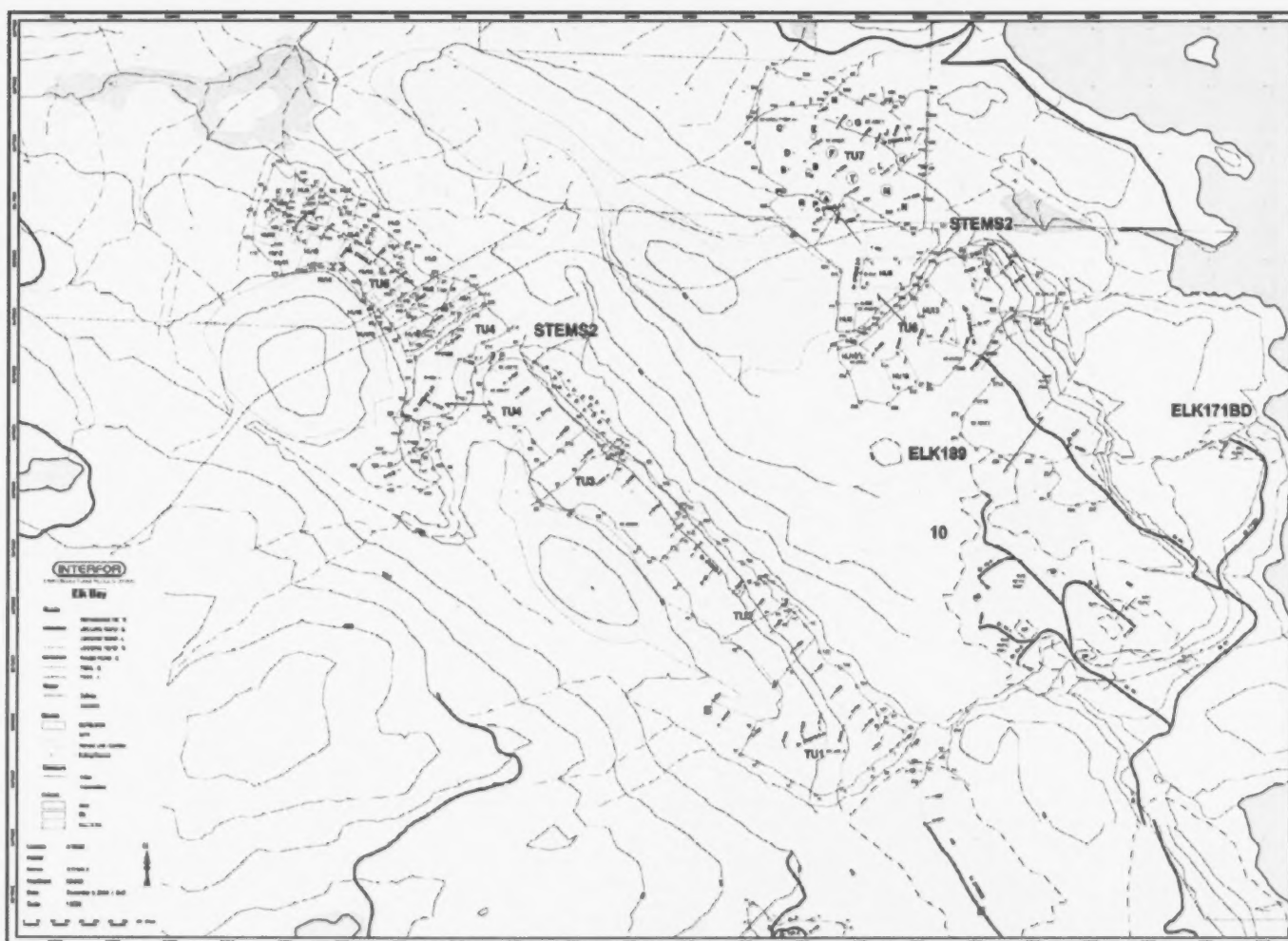


FIGURE A1.3 Base map of STEMS treatment units.

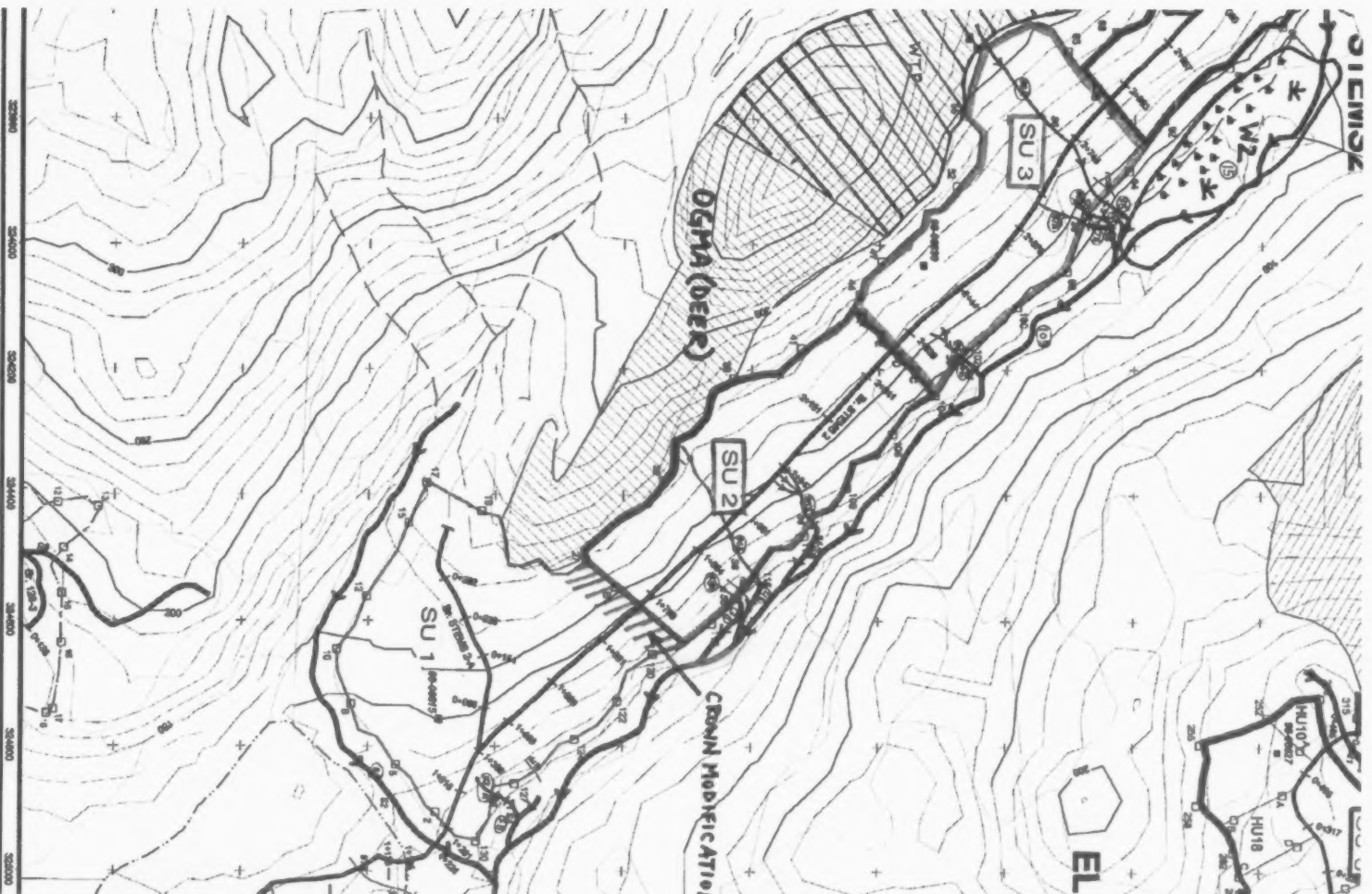


FIGURE A1.4(A) Resource assessment map for Treatment Units 1, 2, and 3.

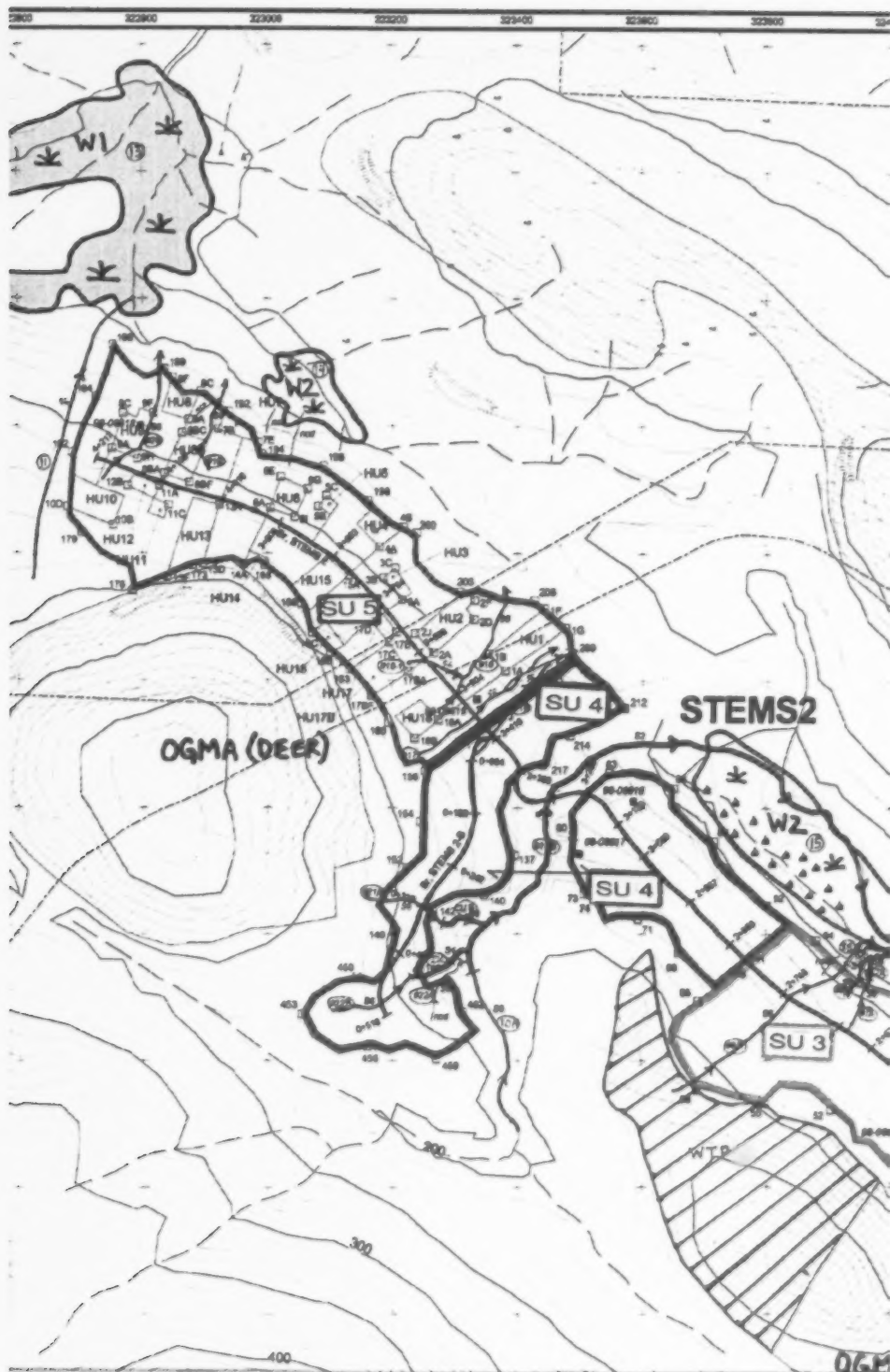


FIGURE A1.4(B) Resource assessment map for Treatment Units 4 and 5.



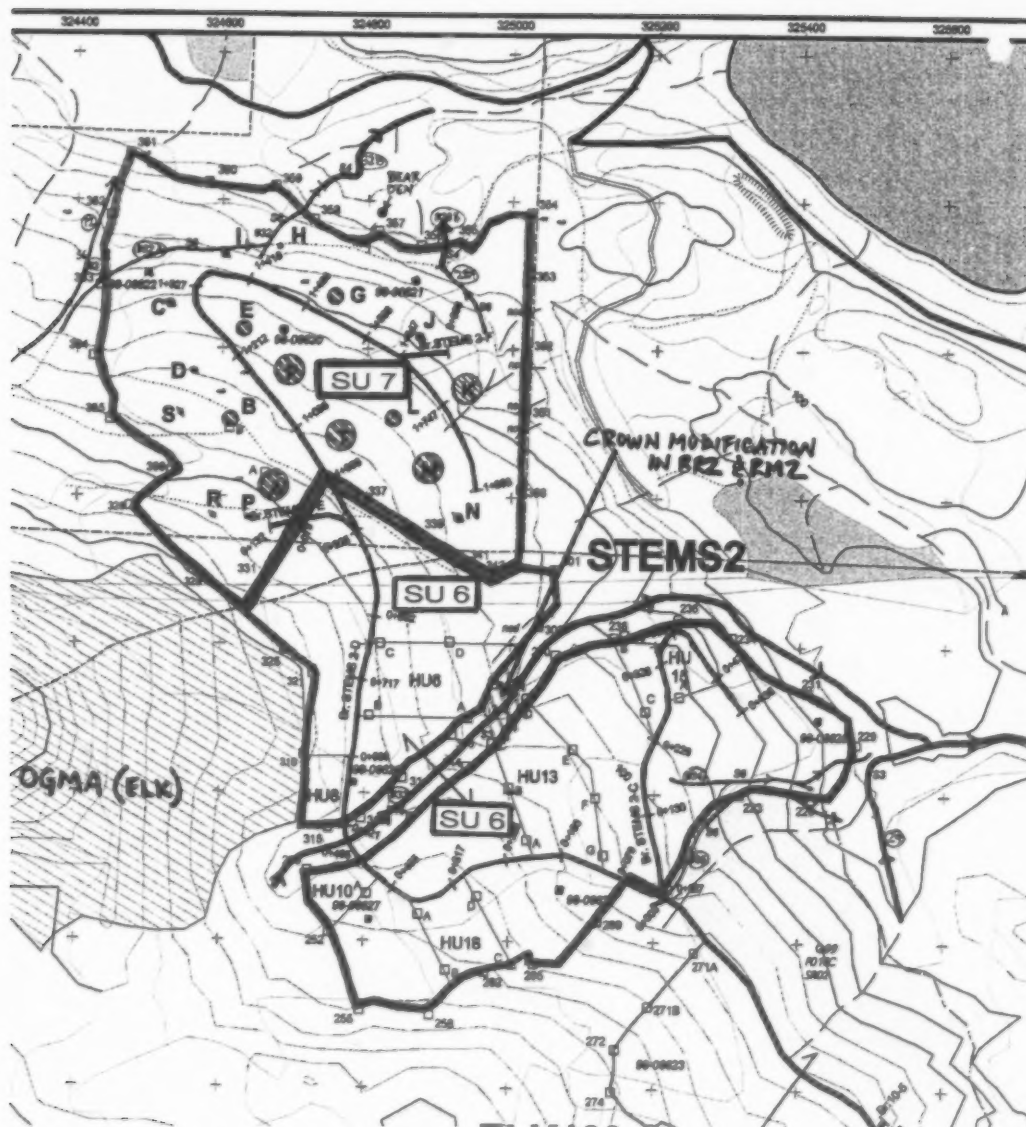


FIGURE A1.4(C) Resource assessment map for Treatment Units 6 and 7.



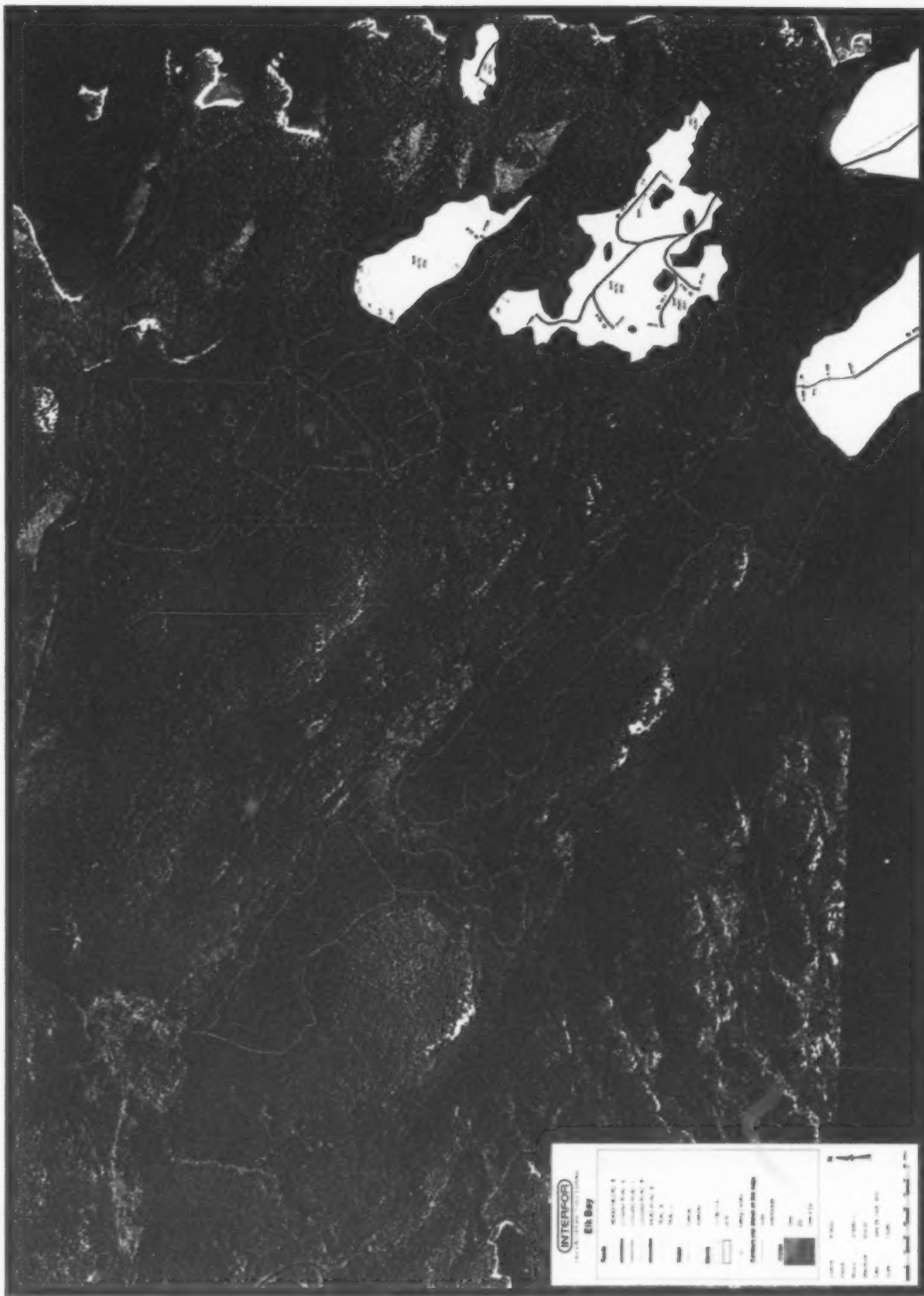


FIGURE A1.5 Pre-treatment ortho-photo of the STEMS experimental area.

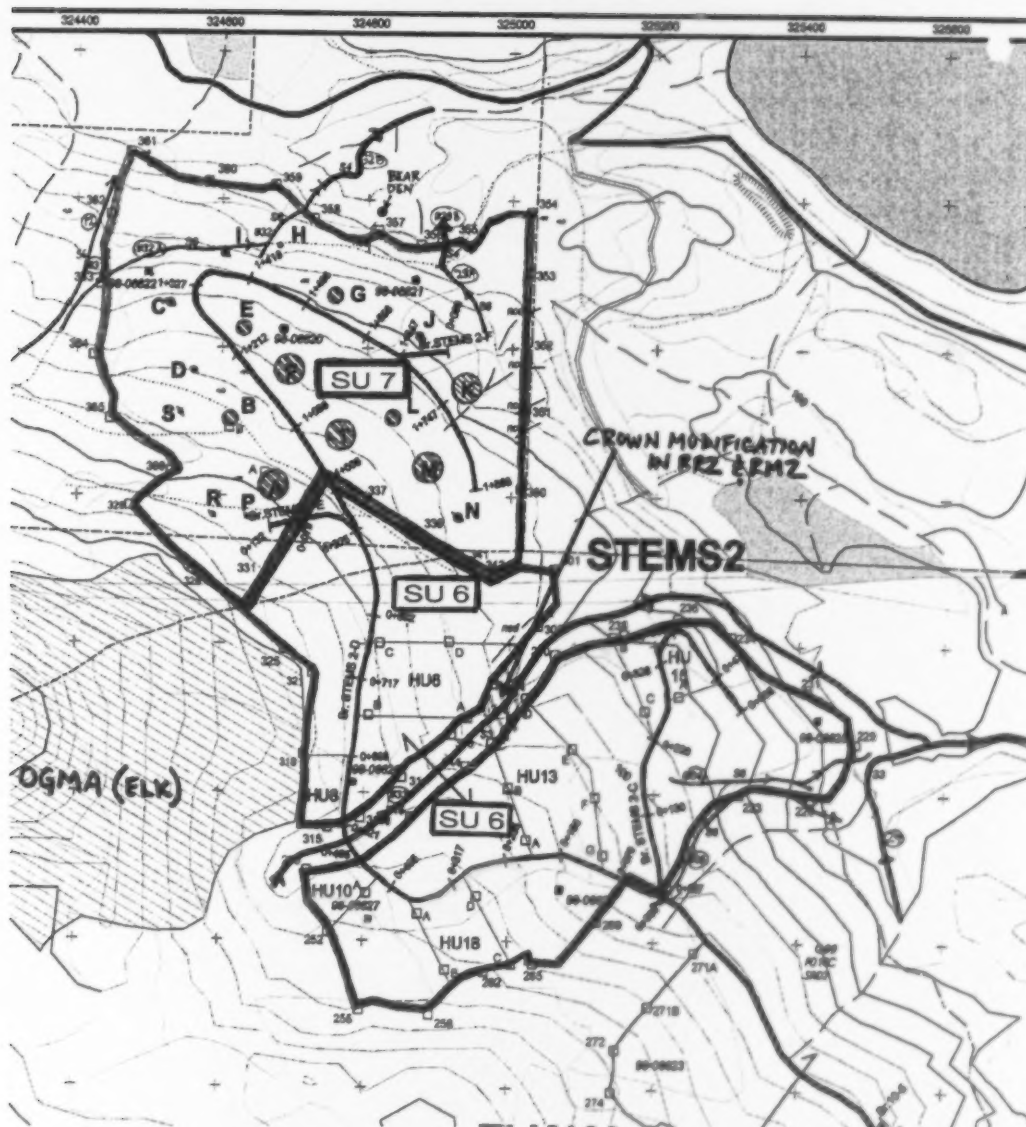


FIGURE A1.4(c) Resource assessment map for Treatment Units 6 and 7.



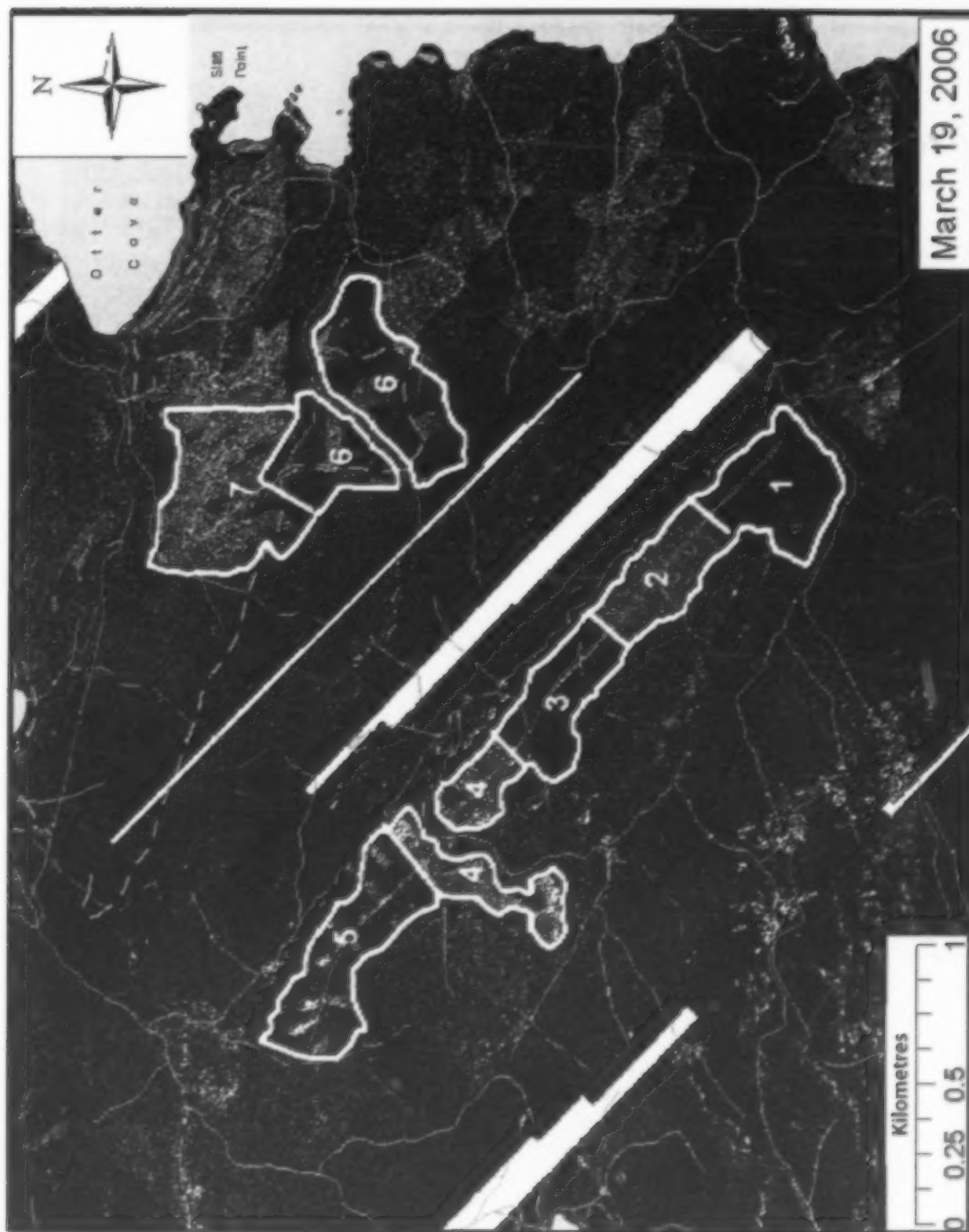


FIGURE A1.6 Post-treatment ortho-photo of the STEMS experimental area.



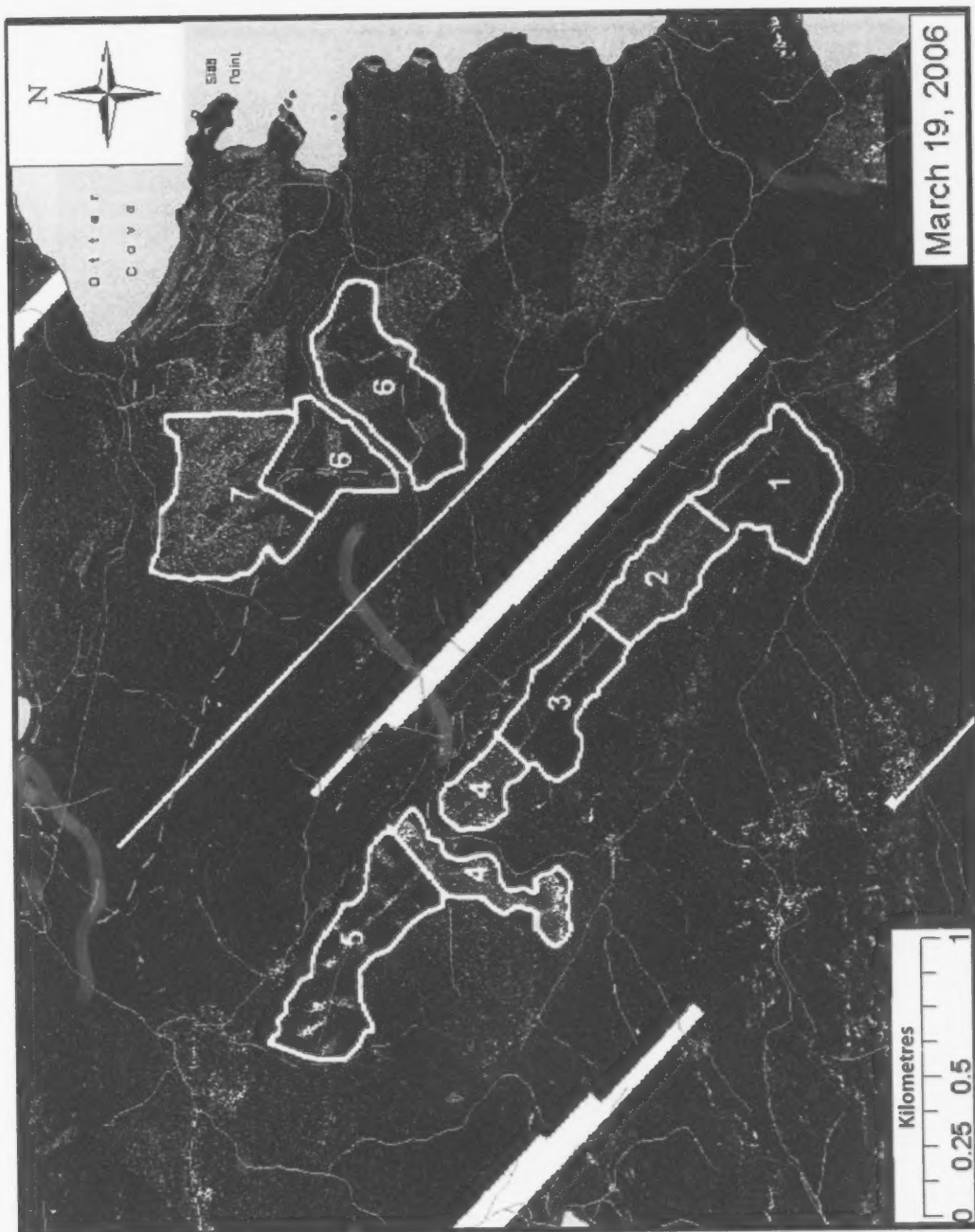


FIGURE A1.6 Post-treatment ortho-photo of the STEMS experimental area.

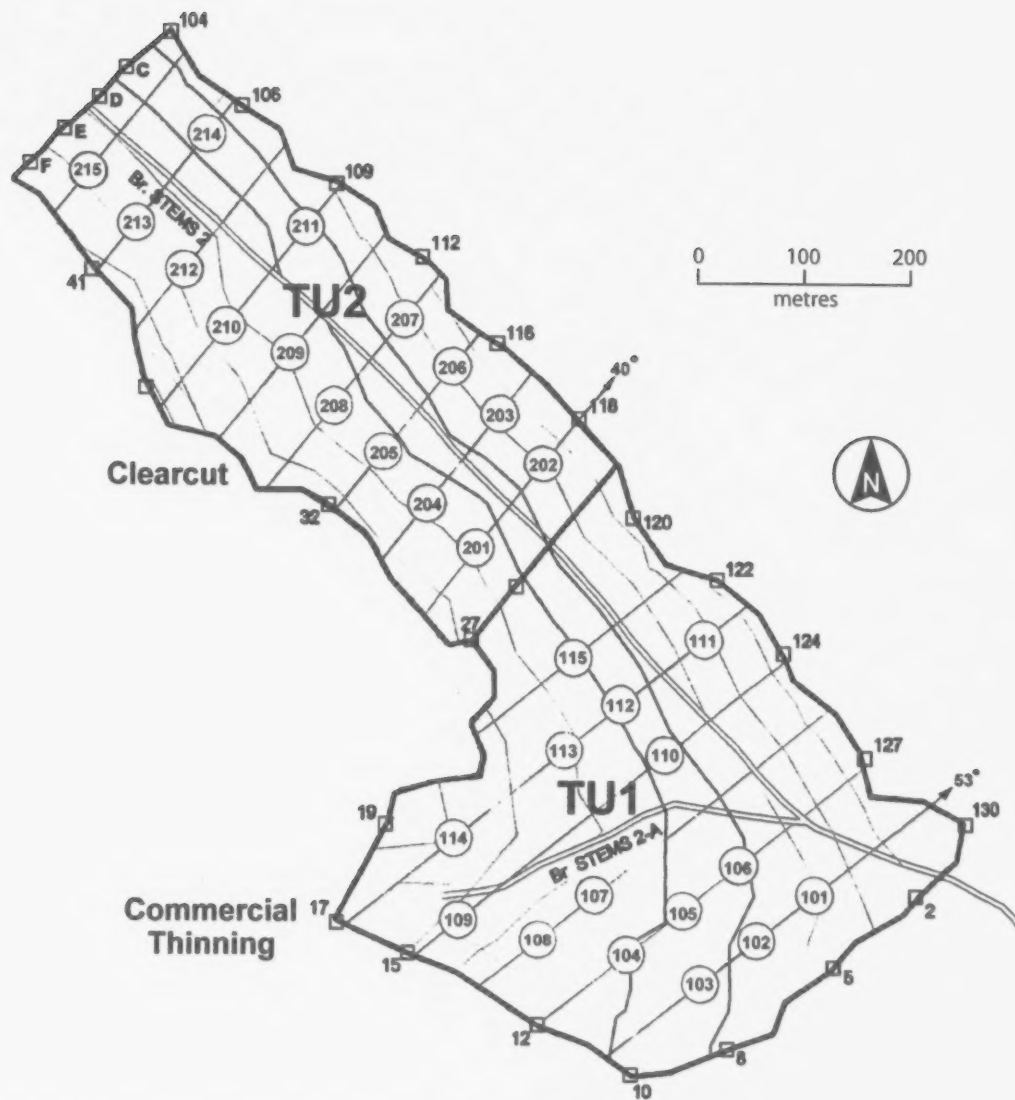


FIGURE A1.7 Plot maps: Treatment Units 1 and 2 (Extended Rotation with Commercial Thinning and Clearcut with Reserves).



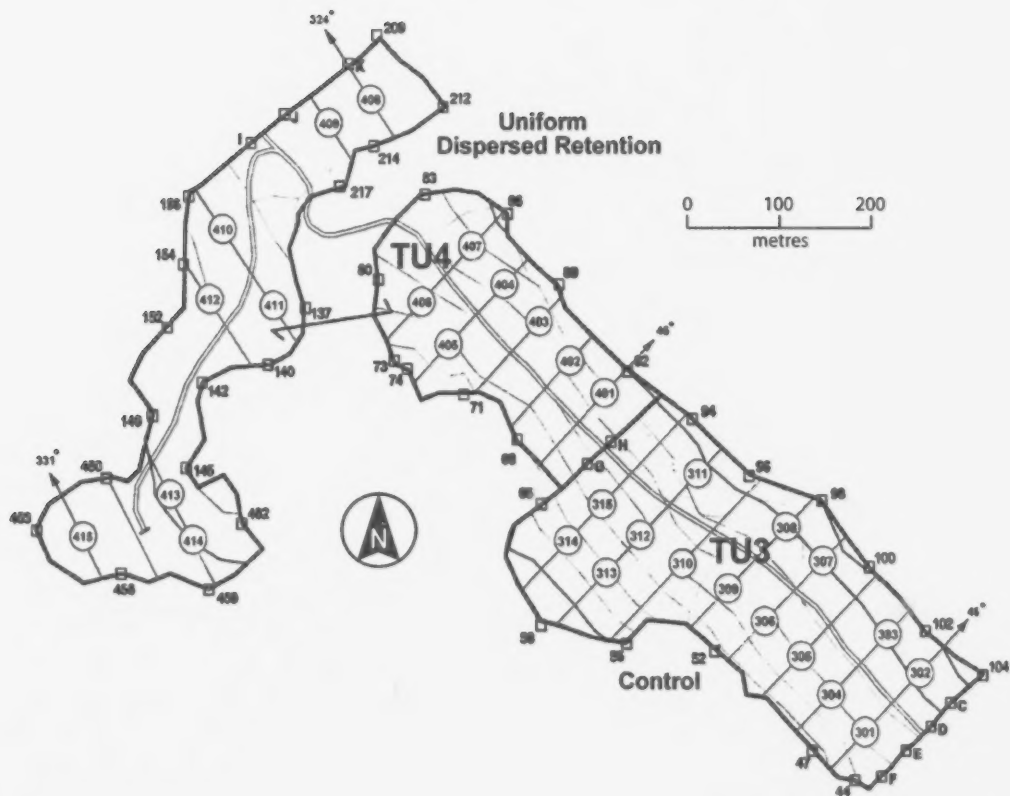


FIGURE A1.8 Plot maps: Treatment Units 3 and 4 (Extended Rotation [non-treatment control] and Uniform Dispersed Retention).

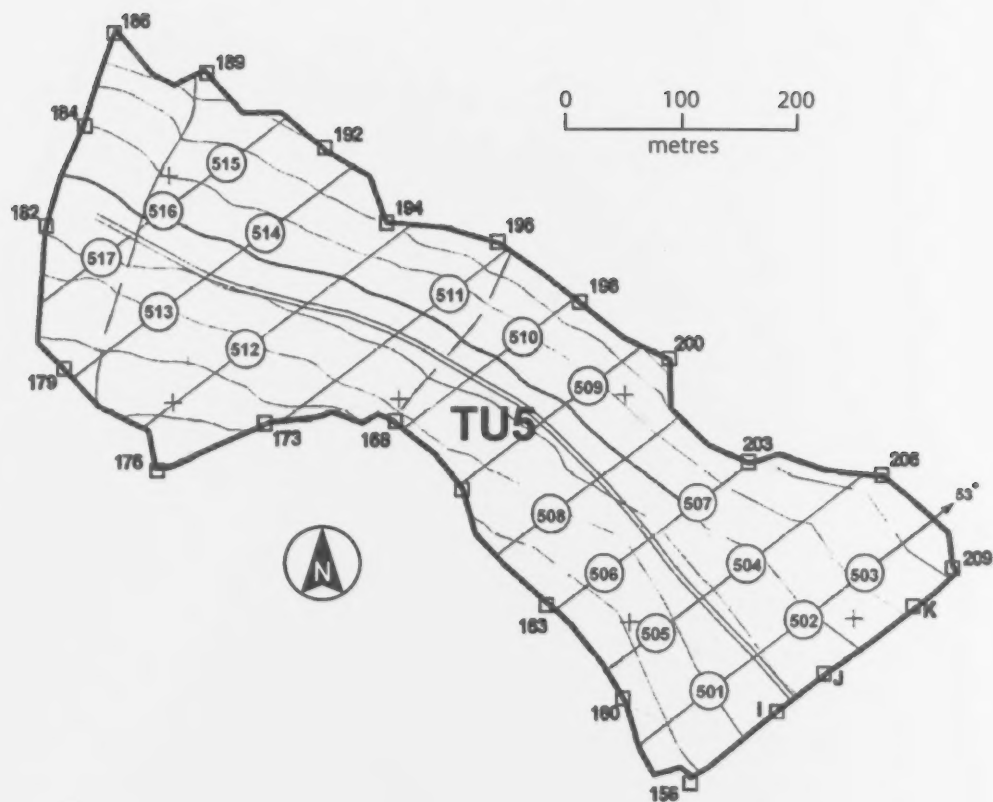


FIGURE A1.9 Plot maps: Treatment Unit 5 (Group Selection).



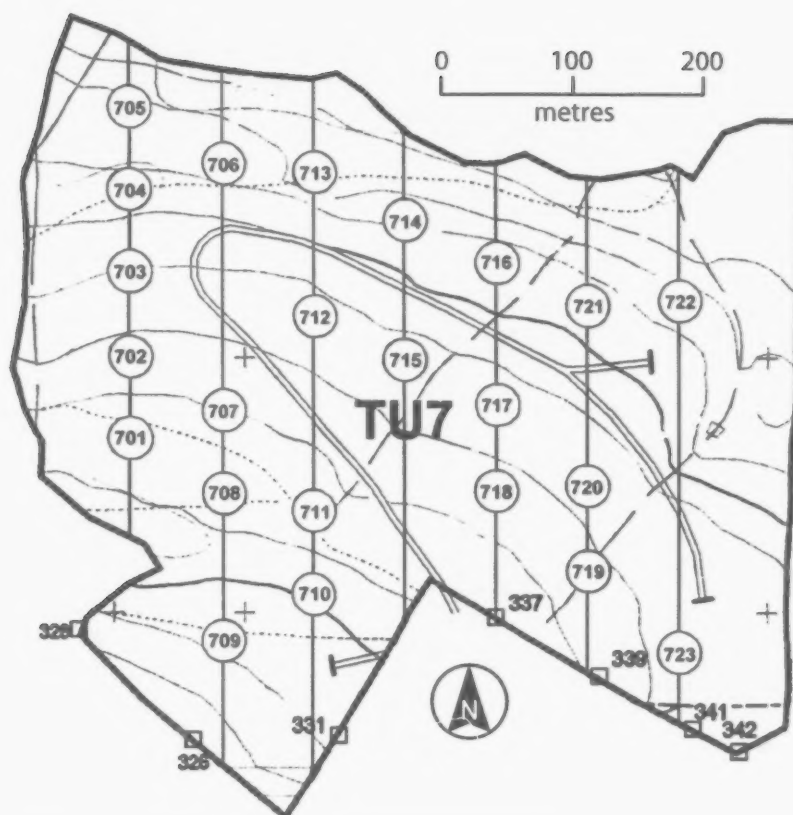


FIGURE A1.11 Plot maps: Treatment Unit 7 (Aggregate Retention).

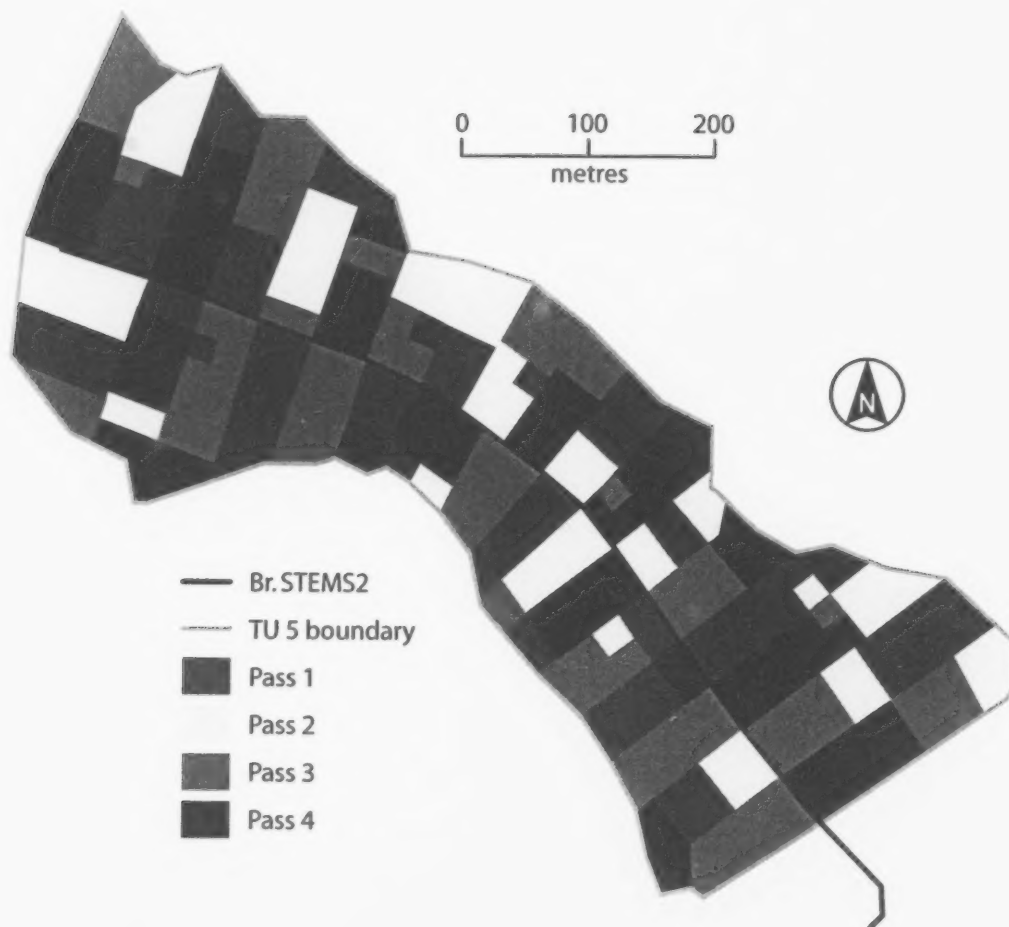


FIGURE A1.12(A) Long-term plan for group selection openings by harvest pass (20-year return interval).

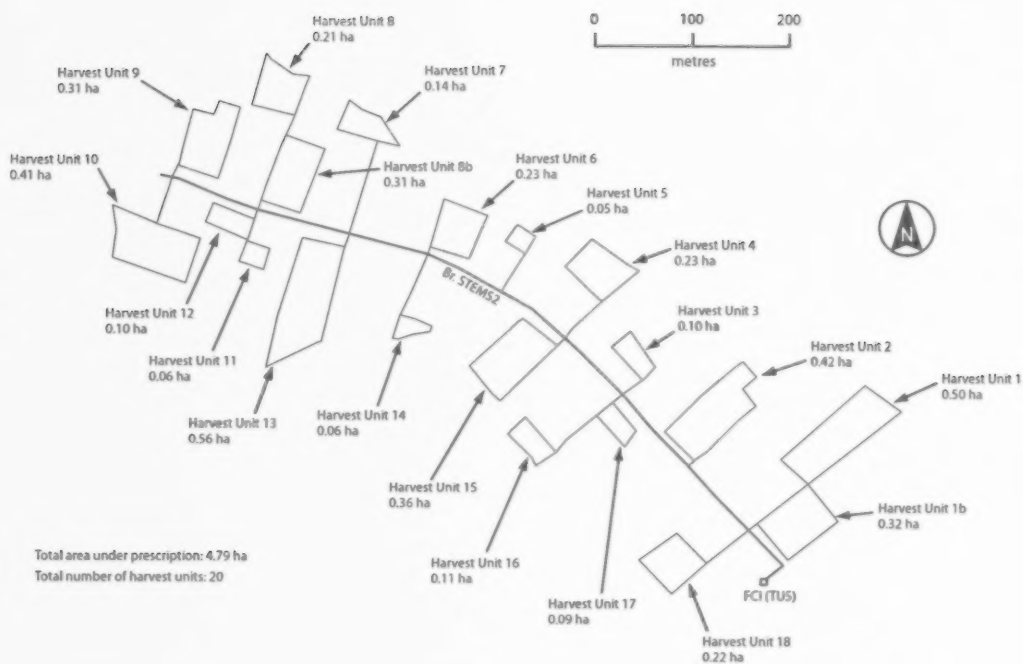


FIGURE A1.12(B) Size and numbering of group selection openings after Pass 1.

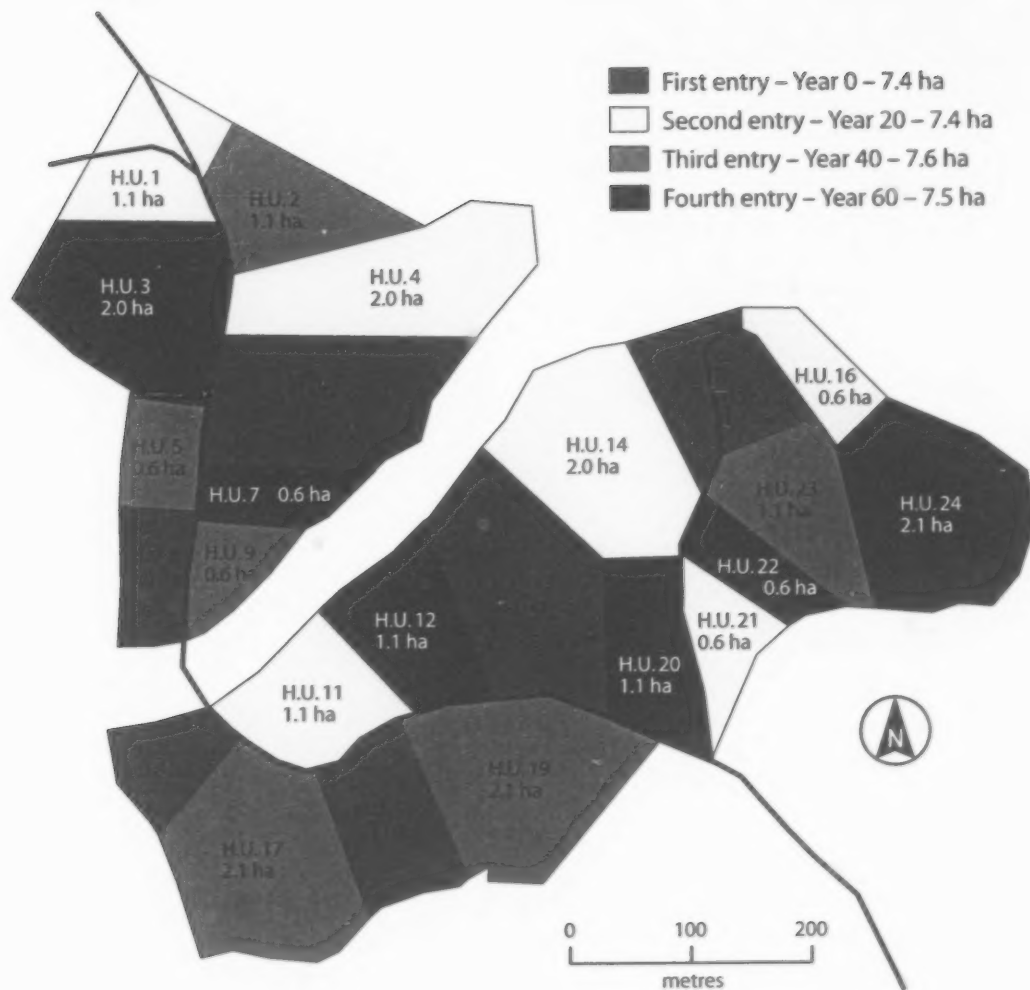


FIGURE A1.13 Long-term plan for the modified patch cuts openings by harvest pass (20-year return interval).



*Reference trees*

At each plot centre, three reference trees were selected and the azimuth and distance to the plot centre was recorded. This information was written on aluminum tags and stapled on the tree below stump height, facing plot centre. The area around the tag was painted orange, and vertical orange bands were painted on the outer sides of the tree. GPS co-ordinates, slope, and aspect were also recorded. (GPS data is a separate file from the pre-treatment full plot data listed below.)

*Tree measurements*

All trees (live or dead) greater than 4.0 cm dbh in all 125 growth and yield plots on the 0.01-ha measurement plots were tagged sequentially commencing from north. Temporary, plastic plot tags were stapled at 1.3 m from the point of germination on the high side and always facing the plot centre. All trees greater than 4.0 cm had dbh measured directly above the tag with a steel diameter tape, recorded in millimetres. Species, crown class, tree class, damage, and disease were also recorded. Dead trees were recorded as having dead or broken tops; if a dead tree had a broken top, then an estimated height was recorded. A top height tree was selected, its height measured, and a "TH" painted below stump height. (The top height tree data file is separate from the general pre-treatment data file.) Heights were then taken on three Douglas-fir and three western hemlock representing small, medium, and large diameter classes. For each additional species in the plot, one sample height was taken. A paint dot was used to indicate which direction the height was taken. All tree heights were measured to the closest decimetre using a Vertex hypsometer.

Additional funding allowed the pre-treatment measurement sample to be expanded to the full 0.10-ha measurement plot in all growth and yield plots. Thus in addition to all trees 4 cm or larger tagged and measured in the 5.7-m plot, trees greater than 15 cm in the 12.6-m plot, and trees greater than 25 cm in the 17.8-m plot, were also tagged and measured using the same procedures as described. From these expanded plots an additional three Douglas-fir and three western hemlock heights were taken from among the larger diameter classes. The tagging for each of the nested plots was clockwise from north and used a different number sequence for each radius. Sectors were marked at cardinal directions for each radius using PVC pins or painted sticks.

*Stump measurements*

Data were also collected for stumps in all 125 growth and yield plots on the 0.01-ha measurement plot. A metal tag was pushed into the stump with an 8-cm nail with the tag facing plot centre. These stump tags were also sequential, commencing from north. Stump measurements, including height at high side, species, top inside bark diameter, and bottom (at 30 cm from the bottom) inside bark diameter, were measured with a steel diameter tape and recorded in millimetres. If the stump top was uneven, then the top was visually "folded down" and top measurement taken at this point.

*Vegetation measurements*

Percent cover and modal height for shrubs were collected for all growth and yield plots in the 0.01-ha measurement plot. Only the four most prevalent shrubs per plot were recorded. If shrubs were present but percent cover was

less than 10%, then the code "TR" (trace) was recorded to indicate that the shrub was not dominating the plot.

*Coding for pre-treatment full plot data  
(tree, stump, and vegetation measurements)*

ALL_OR_SOM:	A(collect All plot data) for first record ONLY
BLOCK_NO:	1 = aggregate retention, 2 = extended rotation with commercial thinning, 3 = uniform dispersed retention, 4 = clearcut with reserves, 5 = modified patch cuts, 6 = extended rotation (non-treatment control), 7 = group selection
PLOT_NO:	Sequential Plot Number
REF_TREE_1:	Reference tree 1
DIST_2_PC1:	Distance of reference tree 1 to Plot Centre (cm)
BEARNG_PC1:	Bearing of reference tree 1 to Plot Centre
REF_TREE_2:	Reference tree 2
DIST_2_PC2:	Distance of reference tree 2 to Plot Centre (cm)
BEARNG_PC2:	Bearing of reference tree 2 to Plot Centre
REF_TREE_3:	Reference Tree 3
DIST_2_PC3:	Distance of reference tree 3 to Plot Centre (cm)
BEARNG_PC3:	Bearing of reference tree 3 to Plot Centre
SHRUB1:	Dominant Shrub 1 (Sw_Fn swordfern, De_fn Deer fern, Hu_by Huckleberry, Salal, Or_Gp)
P_PERCENT_CV1:	Percent Cover of Dominant Shrub 1 (10, 20, 30, 40, 50, 60, 70, 80, 90, 100)
AVG_HT_S1:	Shrub 1 average height (cm)
SHRUB2:	Dominant Shrub 2 (Sw_Fn swordfern, De_fn Deer fern, Hu_by Huckleberry, Salal, Or_Gp)
P_PERCENT_CV2:	Percent Cover of Dominant Shrub 2 (10, 20, 30, 40, 50, 60, 70, 80, 90, 100)
AVG_HT_S2:	Shrub 2 average height (cm)
SHRUB3:	Dominant Shrub 3 (Sw_Fn swordfern, De_fn Deer fern, Hu_by Huckleberry, Salal, Or_Gp)
P_PERCENT_CV3:	Percent Cover of Dominant Shrub 3 (10, 20, 30, 40, 50, 60, 70, 80, 90, 100)
AVG_HT_S3:	Shrub 3 average height (cm)
SHRUB4:	Dominant Shrub 4 (Sw_Fn swordfern, De_fn Deer fern, Hu_by Huckleberry, Salal, Or_Gp)
P_PERCENT_CV4:	Percent Cover of Dominant Shrub 4 (10, 20, 30, 40, 50, 60, 70, 80, 90, 100)
AVG_HT_S4:	Shrub 4 average height (cm)
REG_TALLY:	Tally of natural regeneration by species > 30 cm
HT1_REG:	Height of tallest regen if < 1.3m (cm)
DI1_REG:	dbh of tallest regen if > 1.3m (cm)
HT2_REG:	Height of NEXT tallest regen if < 1.3m (cm)
DI2_REG:	dbh of NEXT tallest if > 1.3m (cm)
STUMP_NO:	Stump No.
S_SPECIES:	Stump Species: Fd, Cw, Hw, Dr (alder), Ss, Bg, Willow, Ct(cottonwood), Dogwood, Yew
ACTUAL_HT:	Actual Stump height (high side) to top (e.g., 105 cm)
M_OR_E:	Stump height M(easured) or E(stimated)
TOP_IB_DIA:	Stump: Top inside bark diameter (mm)
BOT_IB_DIA:	Stump: Bottom inside bark diameter (mm)

PAPER_T_NO:	Paper Tag Tree Number
SPECIES:	Fd, Cw, Hw, Dr(alder), Ss, Bg, Willow, Ct(cottonwood), Dog-wood, Yew
ALIVE_DEAD:	Live (L) or Dead (D)
TOP_CONDIT:	Top Condition DT=dead top, BT=broken top (> 10cm @ break)
BK_HEIGHT:	Height to Break (m)
LEAN?:	Lean 10 deg. or more Yes or No
DBH:	dbh (mm) for all trees $\geq 4$ cm dbh
HEI_TREES:	Tree height (dm)
COMMENT:	Relevant comments
SEQUENCE:	Original sequence number

#### *Plot photographs*

Four photos were taken per plot on a tripod from plot centre facing to each of the four cardinal directions. Each photo has an identification card with plot number and cardinal direction in the photo. The plot identification card in the photo indicates the centre of the photo. The directions were established with a compass and are centre-frame in the photos.

#### *Pre-treatment coarse woody debris sampling*

Pre-treatment CWD surveys were conducted in three TUs: TU 1 (extended rotation with commercial thinning), TU 2 (clearcut with reserves) and TU 6 (modified patch cuts). Line Intersect Sampling (LIS) was used to determine CWD pieces to be measured. Three 25-m transects were established in a spoke pattern radiating out from each growth and yield plot centre pin for a total of 75 m of transect per growth and yield plot. Direction of the first transect was determined using the Vegetation Resources Inventory random-bearing card, with the other two transects located clockwise at 120-degree intervals. Slope distances were corrected to horizontal.

For this study the following definitions apply: trees: self supporting live or dead stems  $\geq 1.3$  m in height and  $\geq 10$  cm diameter inside bark at dbh; stumps: self-supporting stems 0.3–1.29 m in height with a top diameter  $\geq 10$  cm diameter inside bark (natural or cut); and CWD: non-self-supporting deadwood with a top diameter  $\geq 10$  cm diameter inside bark.

Pieces were considered for assessment if at the transect they were  $\geq 10$  cm diameter inside bark for round and elliptical pieces or, in the case of odd-shaped or rectangular pieces,  $\geq 78.5$  cm<sup>2</sup> inside bark. Procedures and recommendations as described in *Using Line Intersect Sampling for Coarse Woody Debris* (Marshall et al. 2000), *Measuring the Length of Coarse Woody Debris* (Marshall and Davis 2002), and VRI rules were used when assessing pieces.

Prior to commencing fieldwork, a pre-work conference attended by the lead field sampler and Ministry staff at Branch office was held to clarify sampling objectives and facilitate accurate, complete data collection. Early in the field data collection phase it was determined that a two-person tally crew would be most efficient for time and accuracy. Both crew persons were VRI certified for CWD measurement. Given the large number of attributes to measure for each piece, one person taking measurements while the other recorded the data on field sheets resulted in a steady flow of data with little downtime for either sampler.

Starting at the 0.0-m point on the transect, pieces were identified and given a sequential number up to the end of the transect. Attributes were measured and recorded as per contract specifications. Pieces were probed with an

axe to determine the percent of sound wood and graded accordingly. Transect, butt, and top measurements were taken using Hagloff 65-cm digital calipers, while lengths were directly measured with nylon or steel tapes.

*Data dictionary, definitions and measurement standards for CWD*

General plot information		
Attribute	Standard	Definition
Treatment Unit	No error	Harvest blocks or Standard Units 1, 2, 6, etc.
Plot #	No error	e.g., 202 = block 2, plot 2
Line #1 Direction	+/- 2 degrees	Direction of transect from random table (VR1)
Line #1 Slope	+/- 2 percent	Slope of transect in %
Line #2 Direction	+/- 2 degrees	Line 1 plus 120 degrees
Line #2 Slope	+/- 2 percent	Slope of transect in %
Line #3 Direction	+/- 2 degrees	Line 1 plus 240 degrees
Line #3 Slope	+/- 2 percent	Slope of transect in %
Transect Length (25m)	+/- 2 percent of total length	Horizontal length in metres of transect (slope corrected)
Piece specific data		
1. Transect #	No error	1, 2, or 3
2. Piece Number	No error	Piece number from beginning of transect
3. Piece Code	No error	Branch, Log, Windfall with roots
4. Species	1 error per sample	Tree species codes
5. Angle	+/- 2 degrees	Vertical angle of piece @ trans in degrees. Place clinometer on straight edge on piece.
6. Orientation	+/- 2 degrees	Horizontal angle @ trans in degrees. Compass bearing from butt end.
7. Shape	N/A	Round, Ellipse, Half ellipse, Slab
8. Diam Reconstructed	N/A	Yes, No. Pieces must be touching
9. Transect IBW	+/- 4% to nearest 0.1 cm	Transect inside bark width (cm)
10. Transect IBH	+/- 4% to nearest 0.1 cm	Transect inside bark height (cm)
11. Transect Bark	+/- 4% to nearest 0.1 cm	Thickness of bark at transect on one side
12. Bark Condition	N/A	Loose, Firm
13. Bark Remaining	Within 1 class	% remaining class: 1) 100%, 2) 100-75%, 3) 75-50%, 4) 50-25%, 5) <25%. No bark coded as 'o'.
14. Transect Intersection Length	+/- 4% to nearest 0.1 cm	Length of transect crossing the piece (cm)
15. Piece/Segment Length to Left	+/- 4% to nearest 0.1 m	Length of piece to left of transect (m)
16. Piece/Segment Length to Right	+/- 4% to nearest 0.1 m	Length of piece to right of transect (m)
17. Butt IBW	+/- 4% to nearest 0.1 cm	Inside bark width @ butt
18. Butt IBH	+/- 4% to nearest 0.1 cm	Inside bark height @ butt

Attribute	Standard	Definition
19. Butt Bark	+/- 4% to nearest 0.1 cm	Butt bark thickness on one side (cm)
20. Butt Description	N/A	New cut (NC), Old cut (OC), Natural (N) – used to describe butts pencil-bucked at 10 cm diameter or sloughed off into ground. Broken (B).
21. Butt IBW @ 0.3 m	+/- 4% to nearest 0.1 cm	For Windfall. Inside bark width @ 0.3 m above high side if roots attached (cm).
22. Butt IBH @ 0.3 m	+/- 4% to nearest 0.1 cm	For Windfall. Inside bark height @ 0.3 m above high side if roots attached (cm).
23. Top IBW	+/- 4% to nearest 0.1 cm	Top inside bark width (cm)
24. Top IBH	+/- 4% to nearest 0.1 cm	Top inside bark height (cm)
25. Top bark	+/- 4% to nearest 0.1 cm	Top bark thickness on one side (cm)
26. Top Description	N/A	New cut (NC), Old cut (OC), Natural (N) – used to describe tops pencil-bucked at 10 cm diameter or sloughed off into ground. Broken (B).
27. Ecological Code (1–5) for transect piece ONLY	Within 1 class	1 = Live or recently dead with bark and twigs < 3 cm intact, 2 = Dead with bark loose and no twigs < 3 cm intact, 3 = Rotting but still round with little bark and few branches intact, 4 = Advanced decay with shape collapsing and no bark or branches intact, 5 = Final stage of decay (oval)
28. Grade for Transect Piece	Within same utilization	As per VRI grading rules
29. Sound Wood Class for Transect Piece Only	Within 1 class	1 = 0–25%, 2 = 25–50%, 3 = 50–75%, 4 = 75–100%
30. Rot	Within 1 class	Saprot, Heartrot, Compound, None
31. Charcoal	N/A	Presence of: Yes/No
32. Inside Bark Diameter 5 m up from butt for logs > 100 cm	+/- 4% to nearest 0.5 cm	Applies to 5-m lengths that are not segmented
33. No. Segments	N/A	Number of segments if piece is broken (identified as S1, S2, etc.)
34. Total Net Log Length	+/- 4% to nearest 0.1 m	Total net length of log if segmented (segments must be < 0.5 m apart)
35. Second Butt IBW	+/- 4% to nearest 0.1 cm	For segmented pieces butt inside bark width (cm)
36. Second Butt IBH	+/- 4% to nearest 0.1 cm	For segmented pieces butt inside bark height (cm)
37. Second Butt Bark	+/- 4% to nearest 0.1 cm	For segmented pieces butt bark thickness on one side (cm)
38. Butt Description	N/A	New cut (NC), Old cut (OC), Natural (N) – used to describe butts pencil-bucked at 10 cm diameter or sloughed off into ground. Broken (B).

Attribute	Standard	Definition
39. Second Top IBW	+/- 4% to nearest 0.1 cm	For segmented pieces top inside bark width (cm)
40. Second Top IBH	+/- 4% to nearest 0.1 cm	For segmented pieces top inside bark height (cm)
41. Second Top Bark	+/- 4% to nearest 0.1 cm	For segmented pieces top bark thickness on one side (cm)
42. Top Description	N/A	New cut (NC), Old cut (OC), Natural (N) – used to describe tops pencil-bucked at 10 cm diameter or sloughed off into ground. Broken (B).
43. Hole Width	+/- 4% to nearest 1.0 cm	Width of hole (cm)
44. Hole Height	+/- 4% to nearest 1.0 cm	Height of hole (cm)
45. Hole Length	To nearest 1.0 m	If can measure, estimate, or based on VRI butt rot table
46. Odd Species	Tree species codes	For accumulations, anomalies, etc. Visually combined into single piece (estimated measurements).
47. Odd Pile/Slab		Describes shape or structure of piece(s)
48. Odd # Pieces		Number of pieces comprising accumulation
49. Odd Width of Rectangle		Width of odd piece(s) along transect
50. Odd Height of Rectangle		Average height of piece(s)
51. Odd Eco Class (1–5)		1 = Live or recently dead with bark and twigs < 3 cm intact, 2 = Dead with bark loose and no twigs < 3 cm intact, 3 = Rotting but still round with little bark and few branches intact, 4 = Advanced decay with shape collapsing and no bark or branches intact, 5 = Final stage of decay (oval)
52. Odd Grade		As per VRI grading rules

The following calculations were used to estimate the cubic metres of CWD per hectare: piece width at transect crossing, piece height at transect crossing, and piece tilt away from the horizontal. The dimensions of the piece were used to calculate the equivalent diameter by using the formula

$$\text{Diameter} = 2(\text{SQRT}((\text{width} \times \text{height})/\pi))$$

The secant of the piece tilt angle was used to correct for the sampling error associated with tilted pieces, which has the effect of increasing the calculated piece volume. Species and decay class are known for each piece of CWD but were not used in the summary.

The plot volumes in cubic metres per hectare are calculated by taking the sum of the squared diameters, corrected for piece tilt, and multiplying it by a constant, in this case 0.016453, for a total sample line of 75 m. The constant is 1.234 for diameters measured in centimetres, line lengths in metres, and calculated volumes in cubic metres and using 1.234/75 gives a multiplier of 0.016453.

**A3.1 Plot  
re-establishment  
and residual tree  
measurements**

Research Branch staff conducted post-treatment plot measurements in July 2005 as harvesting treatments were completed in each operational block. Plot centres in harvested plots were found or re-established according to procedures described.

*Tree numbering*

Trees were tagged and measured by sectors, which were determined by dividing the plot into four along the cardinal directions. Sector 1 was always in the northeast and numbering was sequential in a clockwise direction. All trees 4 cm or larger were tagged and measured in the 5.7-m plot, trees greater than 15 cm in the 12.6-m plot, and trees greater than 25 cm in the 17.8-m plot. Trees were tagged at breast height, facing plot centre. Tree tag numbers started from 1 for each plot. Small, thin-barked trees had tags attached with barlocks and staples. Dead trees and large, live trees with sufficiently thick bark and snags were tagged with aluminum nails. Dead trees less than 25 cm or less than 2.5 m in height were ignored. Trees were measured for dbh and assessed by codes for crown class, tree class, damage, etc. as listed below in the coding. All data were recorded electronically using EASYDC software licensed to Research Branch.

*Site Tree selection*

Tree heights were measured by staff in the fall of 2006 after plots had been re-established and tree diameters and condition codes were taken. The site tree, defined as the largest Douglas-fir tree in a 0.01-ha plot, was measured for height if suitable. Suitability was met if the tree was a dominant or codominant, not a wolf or veteran or open-grown tree, with a straight stem free of disease, damage, or breakage, free of suppression above breast height, not repressed and vigorous, and with a full crown. If a suitable site tree could not be found on the inner 5.7 m radius plot, then the 12.6 m radius plot was subdivided into five sectors and a suitable tree was chosen within the newly defined 0.01-ha plot in the northeast sector. If this approach was still unsuccessful, the sectors were sequentially scanned until a suitable tree was found.

*Tree height and height to base of live crown*

All Douglas-fir trees larger than 25 cm were measured for height and height to base of live crown. Where crown base was uneven, an average was used. Height and height to live crown of species other than Douglas-fir were subsampled. For western hemlock and western redcedar, one tree was randomly selected for each of the three diameter classes (4–15 cm, 15.1–25 cm, and > 25 cm). For other species, such as Sitka spruce, bigleaf maple, and grand fir, one tree was randomly selected across all diameter classes. Dead trees greater than 25 cm were assessed for height to break, condition, etc. as listed in the coding below.

*Tree harvest damage*

Tree harvest damage data were collected for each tree with visible damage. Measurements included tree number, species, dbh, type of stem damage (surface scuffed or bruised, phloem exposed, wood gouged < 1 cm deep, wood gouged > 1 cm deep, tree stem damaged at the ground), cause of stem damage (yarding, falling, windthrow), width of damage, diameter of tree at point of



damage, percentage of stem damaged, length of damage, lowest point above ground (cm), location of damage (thirds), and damage to root system. Where more than one scar was present, the width and lengths of all scars on the same tree were added together. Coding is listed below.

*Coding for post-treatment measurements:*

T_UNIT:	Treatment Unit Number
PLOT_NO:	Plot Number
MEAS:	Measurement Number
SECTOR:	1=N-E, 2=E-S, 3=S-W, 4=W-N
PAPER_T_NO:	Old Tree Number
SPECIES:	Fd, Cw, Hw, Ss, Ba, Bg, D
ALIVE_DEAD:	Live (L) or Dead (D)
DBH:	dbh in mm
HEI_TREES:	Height in dm
HT_TREE:	If height tree - put in x
TREECLASS:	1 = residual, 2 = suspect, 3 = dead potential, 4 = dead useless, 5 = veteran, 6 = live useless, 7 = dead potential vet, 8 = immature, 9 = dead potential immature
CC (Crown Class):	1 = dominant, 2 = codominant, 3 = intermediate, 4 = overtopped, 6 = understorey
HTBASECR:	Height to Base of Crown (dm)
DAM (DAMAGE):	0 = none, 1 = unhealthy, 2 = mechanical, 3 = chemical, 4 = disease, 5 = insects, 6 = animal, 7 = weather, 8 = suppression
LEANSWP (LEAN/SWEEP):	1 = lean, 2 = sweep, 3 = broken top, 4 = twin below dbh, 5 = forked above dbh, 6 = scar, 7 = crooked, 8 = poor top
LEADERCOS (Leader Condition):	1 = dead leader, 2 = new leader, 3 = multiple leaders, 4 = leader missing
TOP_CONDIT (Top condition):	DT=dead top, BT=broken top
HT2BREAK :	Height to Break (dm)
LEAN:	Lean Y or N
STEMSCAR:	0 = no scar, 1 = scar to 22 cm <sup>2</sup> , 2 = scar 22-30 cm <sup>2</sup> , 3 = scar 30-45 cm <sup>2</sup> , 4 = scar >45 cm <sup>2</sup>
C:	Comment 2004
N:	Original Sequence Number

*Tree age cores*

Tree cores were taken from one tree in each plot where there was at least one standing tree in the plot. Trees chosen were the standing tree closest to the plot centre on the north side. Cores were stored in straws and kept in a refrigerator until mounted, sanded, and scanned using Windendro.

### **A3.2 Tree regeneration**

Regeneration and vegetation were assessed on a 3.99 m radius (0.005-ha) plot located on each cardinal point 17.8 m from the permanent plot centre (main plot is 0.10 ha). Surveys were done on all harvested plots, which varied with treatment.

Within the marked circumference of the subplot, all planted trees were tagged and measured, and naturally regenerated trees tallied as described below. Distance from the plot centre to the stem centre of trees situated close to subplot boundaries were accurately measured, to determine whether the tree was included as a sample tree.

Tags were attached to wire and looped very loosely around the base of the seedling. Species was identified and height measured to the nearest centimetre. Root collar diameter was measured using calipers to the closest millimetre. Seedling health was assessed using appropriate coding listed below.<sup>1</sup>

For natural regeneration, the following tree size classes were identified:<sup>2</sup>

- germinants (< 10 cm tall)
- seedlings (10 cm–1.3 m height)
- saplings (> 1.3 m height but < 4 cm dbh)

Only the tallest and second-tallest acceptable seedlings<sup>3</sup> in the subplot were tagged and measured. Tags were attached to wire and looped loosely around the base of the seedling. Species was identified and the seedling measured for height to the nearest centimetre. Root collar diameter was measured using calipers to the closest millimetre. Seedling health was assessed using appropriate coding<sup>4</sup> as listed below.

Photographs of each plot were taken from the south boundary of the subplot facing towards the subplot centre post. The corresponding plot number and photo number were recorded.

#### *Coding for tagged regeneration*

INSTAL:	Installation (DEFAULT=elk)
BLOCK:	Block number
PLOT:	Plot number
SUBPLOT:	Subplot number - 1 = N, 2 = E, 3 = S, 4 = W (3.99 m radius)
ORIGIN:	Origin of seedling - PL=planted, NA=natural
S_TYPE:	Shade environment - FS = forest shade, SSG = south side of small gap, NSG = north side of small gap, MSG = middle of small gap, SLG = south side of large gap, NLF = in forest north of large gap, OP = north of large and small gaps (Note: small gap is < 1.5 ht of dominant tree)
SPECIES:	of measured tree - Fd = Douglas-fir, Cw = western redcedar, Hw = western hemlock, Bg = grand fir, Pw = western white pine, Lw = western larch, Dr = red alder, Ep = paper birch, Act = black cottonwood, Mb = bigleaf maple
TREENO:	Tag number
GLD:	Diameter at ground level (mm)
HEIGHT:	Regeneration height (cm)
DBH:	Diameter at breast height (mm)
SURCODE:	Survival coding - 0 = alive, 1 = dead, 2 = pulled out, 3 = missing, 4 = poor vigour, 5 = good vigour
LDRCODE:	Leader code - H = healthy, C = curled, F = forked, M = multiple leader, B = browsed, T = dead terminal bud, S = snapped/broken, A = absent, Z = stunted needles, O = other

<sup>1</sup> Based on coding established by the Expert Committee on Weeds.

<sup>2</sup> Tree size classes are from the Stocking and Free Growing Survey Procedures Manual May 2002, Forest Practices Branch, B.C. Ministry of Forests.

<sup>3</sup> An acceptable seedling is one that is free from deformity or injury likely to prevent development into a merchantable tree.

<sup>4</sup> Based on coding established by the Expert Committee on Weeds.

LDRDAM:	Leader damage - A = none, M = mechanical, S = falling slash (human), X = falling debris, E = climate-frost, N = snow press, V = vegetation press, W = climate-drought, R = rodents, B = big game, F = fire, I = insects, D = disease, O = other (specify), U = unknown
FOLCODE:	Foliage code - H = healthy, Y = chlorotic, M = mottled, N = necrotic, A = needles absent/defoliated, B = browsed, D = dead buds on laterals, L = lammas growth, O = other (specify)
FOLDAM:	Foliage damage code - A = none, M = mechanical, S = falling slash (human), X = falling debris, E = climate-frost, N = snow press, V = vegetation press, W = climate-drought, R = rodents, B = big game, F = fire, I = insects, D = disease, O = other (specify), U = unknown
REMARKS:	Comments
DATE:	Date of measurement

### A3.3 Vegetation assessments

Vegetation assessments were done using the same plots as for regeneration, a 3.99 m radius (0.005-ha) plot located 17.8 m from the permanent plot centre at each cardinal point. Vegetation assessments were done in all subplots in July 2007 for all plots.

Vegetation assessments were based on a modification of the Vegetation Resource Inventory (VRI) Field Cards 14 and 15 with a plot size of 3.99 m (50 m<sup>2</sup>) (see [www.for.gov.bc.ca/hts/vri/forms/index.html](http://www.for.gov.bc.ca/hts/vri/forms/index.html)). All trees, shrubs, and herbs were identified to the species level, but grasses, sedges, rushes, and bryoids were identified to the family level. Species with less than 1% cover were indicated as trace.

The following data were collected:

- Overall percent cover of:
  - all vegetation
  - all trees and shrubs in layer A (> 10 m)
  - all trees and shrubs in layer B<sub>1</sub> (2–10 m)
  - all trees and shrubs in layer B<sub>2</sub> (< 2 m)
  - all herbs in layer C
  - all bryoids in layer D (if there was more than just mosses, it was noted in comments)
- Cover (%) of trees and shrubs by genus and species in the A layer (> 10 m)
- Cover (%) and modal height by genus and species of:
  - trees and shrubs in the B<sub>1</sub> and B<sub>2</sub> layers
  - herbs in the C layer. For grasses, sedges, and rushes, family level was acceptable.
- For natural regeneration the following were collected:
  - species identified
  - actual number of stems (except for germinants) counted and recorded
  - germinants are tallied as follows: A = 1, B = 2–5, C = 6–9, D = 10–19, E = 20–29, etc.
  - modal height was measured for the seedling size class only
- The position of the plots with respect to canopy openings was specified as *in opening*, *not in opening*, or *overlapping*. If the whole plot was classified as *in opening* or *not in opening*, the same classification was assigned to

each quadrant. If the plot was classed as *overlapping*, then each quadrant within the plot was also classed as *in opening*, *not in opening*, or *overlapping*. Classification was based on vertical projection of crowns of surrounding trees.

#### *Coding for vegetation assessments*

INSTAL:	Installation
BLOCK:	Block Number
PLOT:	Plot Number
SUBPLOT:	Subplot Number (3.99 m radius) - 1 = N, 2 = E, 3 = S, 4 = W
CANOPY:	Canopy Influence - Code 1 = in opening, 2 = overlapping, 3 = not in opening
REGEN:	Regeneration Code - GE = germinant < 10 cm, NTR = natural tree > 1.3 m in height and > 4 cm dbh, NSA = natural sapling > 1.3 m and < 4 cm dbh, NSD = natural seedling > 10 cm and < 1.3 m in height, PTR = planted tree > 1.3 m in height and > 4 cm dbh, PSA = planted seedling > 1.3 m and < 4 cm dbh, PSD = planted seedling > 10 cm and < 1.3 m in height
LAYER:	Layer Code - A = Trees and shrubs > 10 m, B1 = Trees and shrubs 2 - 10 m, B2 = Trees and shrubs < 2 m, C = Herbs, D = Bryoids, Lichens are listed as a remark
SPECIES:	Species Code (see Appendix 4)
COV07:	2006 Percent Cover, 1-100%, < 1 % = trace (t)
MODHT07:	2006 Modal Height (cm)
TAL07:	2006 Tally for Number of Germinants - F = 30-39, G = 40-49, H = 50-59, I = 60-69, J = 70-79, K = 80-89, L = 90-99, M = > 100
DEN07:	2007 Density - count all germinants up to 29
REMO7:	2006 Remarks
DATA REC:	2006 Data Recorder
VEG_ASS:	Name of Assessment Person
DATE07:	2006 Date of Survey

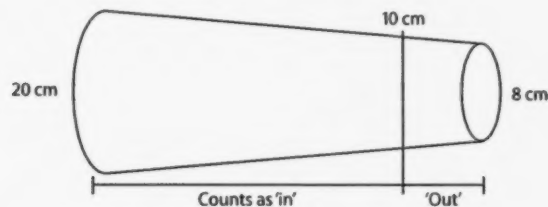
#### **A3.4 Coarse woody debris**

The post-treatment transect lines were located in the same location and used the same methodology as the pre-treatment survey. In TU 6 (modified patch cuts) the sample lines within the untreated areas were generally visible at each plot centre. The CWD piece data collected during the pre-logging survey were found to be generally intact and duplicated as part of the post-treatment survey. All new CWD material was then added to the pre-logging data. In TU 1 (extended rotation with commercial thinning) and TU 2 (clearcut with reserves), all sample plots were re-established and surveyed for new data. TU 6 (modified patch cuts) required re-measurement of the eight plots within the logged patches. The remaining plots were reviewed for any new pieces since the pre-logging survey in 2004.

TU 2 was clearcut logged, and logging debris was piled throughout the block and along the roadsides after logging. When these debris piles were located on a line transect, the line transect affected was completed by using the bounce back method (VRI manual). This required ending the line at the pile edge and continuing the line back along its original bearing until the full length is sampled. The piles were then sampled by establishment of fixed-radius plots (Marshall and Davis 2002).

All debris piles were counted and the area covered by each pile visually estimated in square metres. The total number of piles counted was 252, representing a total pile area of 5060 m<sup>2</sup> (0.51 ha). Piles to be sampled were randomly selected.

If the pile was large, only a portion was sampled. For example, if CWD was assessed in only 30% of a landing pile, then we recorded that 30% was the proportion sample—provided that the CWD was spread evenly through the pile. If the CWD was not evenly distributed, we adjusted the proportion sampled based on the proportion of total CWD present in the 30% of the landing pile that was assessed. CWD pieces included in the sample had both end diameters  $\geq 10$  cm (inside bark) and were  $> 3.0$  m in length or had one inside bark diameter  $\geq 10$  cm at the large end and had  $> 3.0$  m in length from there to the 10 cm diameter (inside bark) cutoff point—then only that portion of the piece qualifies as CWD (see diagram). For example, a piece with a large end diameter of 20 cm and a small end diameter of 8 cm is assessed from the 20-cm end down to the 10-cm cutoff point:



The portion of the piece labelled "Counts as 'in'" qualifies as CWD only if the distance from the 20-cm end to the 10-cm diameter cutoff point is  $> 3.0$  m.

Piece diameter measurements in piles and accumulations are inside bark because the ends are visible, but, if not visible, the location of the 10-cm inside bark diameter cutoff point was estimated. In the line transect sampling procedures for dispersed pieces, CWD piece diameters were taken outside bark (if bark was present) using calipers, because the pieces were generally lying on the ground.

Subsequent periodic sampling of CWD to determine state of decay and recruitment will be done during plot remeasurement if funding is sufficient. Future wildlife studies can be done to determine habitat suitability over time, as a separate study. Coding for post-treatment surveys is the same as for pre-treatment.

### A3.5 Soil disturbance

Soil disturbance was surveyed under contract as described in the "Survey methods for soil disturbance and forest floor displacement" and "Transect method for areas 10 hectares and smaller" sections (pp. 29–37) of the *Soil Conservation Surveys Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1997). The surveys were done in February 2006.

At STEMS 2, the strata identified were simply the TUs. Surveys were done only in harvested areas, hence the extended rotation (control) and unharvested areas within the modified patch cuts and group selection treatments were not surveyed.

The starting and ending location of each transect line used in the survey of each stratum were field marked with either "start" or "end," transect-distinguishing identification number or letter, and bearing in azimuth. For each stratum surveyed, soil disturbance summary information was recorded as listed in Field Card FS 889 HSP 96/10.

The contractor recorded the approximate location of strata and transect lines (field information developed in previous subsections) by sketching a site map on the back of Field Card FS 889 HSP 96/10. The site map included the approximate location of north arrow, strata unit boundary in relation to identifying feature (e.g., road or major stream), prevailing yarding direction, baseline location (if used), and starting and ending point of each numbered transect line.

Soil disturbance and forest floor displacement categories were recorded on Transect Survey Field Card FS 885 HSP 96/8. Soil disturbance survey summary information was calculated on Small Area Survey Calculation Card FS 897 HSP 96/9. Photographs were taken of representative examples of soil disturbance categories found in each stratum.

For each stratum surveyed, the contractor briefly summarized the results, including the site description, survey results, most common soil disturbance categories observed, and impressions of the regeneration potential for the sites compared with the adjacent area.

All survey site write-ups, site map(s), transect survey field cards, and photographs (identifying the associated soil disturbance category) were submitted and are on file.

#### **A3.6 Windthrow surveys**

For each growth and yield plot throughout the installation, a visual sweep of the entire plot was done to find trees that had been windthrown or broken, or were leaning. For those trees affected, data were collected as listed below.

##### *Windthrow coding*

PLOT_NO:	Plot number
PAPER_T_NO:	Pre-treatment paper tag number
NEWTAG:	Post-treatment metal tag number
SPECIES:	Fd, Cw, Hw, Ss, Ba, Bg, D
ALIVE_DEAD:	Live (L) or Dead (D)
NEW DBH:	Post-treatment (mm)
OLD DBH:	Pre-treatment (mm)
NEW HEIGHT:	Post-treatment height in dm
OLD HEIGHT:	Pre-treatment height in dm
LEAN/SWEEP:	1 = lean, 2 = sweep, 3 = broken top, 4 = twin below dbh, 5 = forked above dbh, 6 = scar, 7 = crooked, 8 = poor top
HT2BREAK:	Height to break (dm)
LEAN:	Lean - Y or N
COMMENTS:	Taken at time of post-measurement residual tree survey
STAT07:	LL = live leaning, LS = live standing, WT = windthrown or up-rooted, DS = dead standing, LB = live broken, DB = dead broken, LT = live with thin top, LP = live pruned or topped, LC = live crown broken
AZIM07:	Azimuth of tree from base to tip
DBH07:	measured in 2007
COMMENT 07:	Comments about the windthrow

Edge measurements were also conducted at STEMS 2 in July 2007. The procedure is described as follows (see Figure A3.1 for an example of how data were collected).

1. Locate tie point that is easily identifiable on map or air photo and record Point of Commencement (POC) northing and easting as measured by hand-held GPS.
2. Begin traverse notes on left side of book and map edge to 1:5000 scale on right side of book.
3. Record random half sweeps with 4BAF prism to record basal area in parts of edge that are not windthrow-affected.
4. Create a station wherever windthrow occurs and subsequent stations every 20 or 30 m through any windthrow patches.
5. Record half sweeps with 4BAF prism along windthrow-affected edge segments.
6. Record the extent and the azimuth of windthrow patches. Note that the extent is determined by the location of the root system of the farthest up-rooted tree.
7. Dominant orientation of individual trees affected by windthrow is indicated graphically on the mapping side of the notes with relative numbers of trees affected (e.g., one tree drawn in notes indicates isolated trees affected, two trees indicates small patch, and three or more trees indicates larger patch). The orientation of individual trees will be deduced from the azimuth along the traverse in the field notes. Dotted lines were used to indicate the shape and size of any large patches of windthrow, and information regarding significant landmarks such as road location and orientation and block corners were also recorded on the mapping side of the notes.
8. Traverse may be open, with Point of Termination (POT) identified by new GPS co-ordinates, or closed, by returning to the POC. Long stretches of edge, which were obviously not affected by windthrow, were not traversed.



ST#	AZ	HD	VD	$\frac{BA}{HA}$ Z	AZ	HD
01892				0	244	6.91
	134	13.26	-1.13			
01879						
	121	22.13	0.11			
01857				12	254	3.59
	144	16.85	-0.78			
01840						
	133	16.95	0.52			
01823				0	272	3.22
	162	12.55	1.20			
01801						
	228	25.54	10.87			
01785				24	316	10.01
	226	29.12	6.77			
01766				20	318	13.96
	228	26.11	5.50			
01748				0	321	51.6
	231	26.06	4.73			
01714				0	316	50.76
	226	30.76	6.52			
01683				12	314	47.53
	224	24.12	4.00			
01659				16	320	44.23
	230	13.52	1.34			
01645				20		
	225	54.50	0.22			
01593				12	230	7.92
	320	22.8	-0.16			
01568						

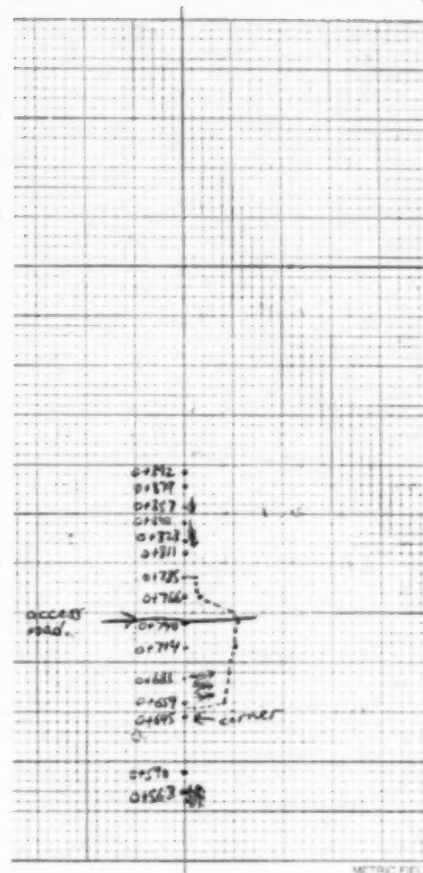


FIGURE A3.1 Example of how the windthrow survey information was collected.

### Coding for windthrow edge survey

Station:	Position along the transect
Azimuth:	Bearing of the transect
HDistance:	Horizontal distance along the transect
VDistance:	Vertical distance from past station
halfBA_HA:	Half sweep of basal area per hectare
WT_Azimuth:	Direction of tree fall
WT_HDistance:	Position along the transect where multiple stems fell
WT_dom_orientation:	Dominant orientation (or average direction of fall) of the multiple stems
Easting:	Number of metres east of the reference meridian using UTM GPS co-ordinates
Northing:	Number of metres north of the equator using UTM GPS co-ordinates

**APPENDIX 4** Species names

Species code	Scientific name	Tree code	Common name
ACERMAC	<i>Acer macrophyllum</i>	Mb	bigleaf maple
ACHIMIL	<i>Achillea millefolium</i>		yarrow
ACHLTRI	<i>Achlys triphylla</i>		vanilla leaf
ADENBIC	<i>Adenocaulon bicolor</i>		pathfinder
ALNURUB	<i>Alnus rubra</i>	Dr	red alder
AMELALN	<i>Amelanchier alnifolia</i>		saskatoon
ANAPMAR	<i>Anaphalis margaritacea</i>		pearly everlasting
ANTERAC	<i>Antennaria racemosa</i>		racemose pussytoes
AQUILEG	<i>Aquilegia</i> sp.		columbine
ARTEMIS	<i>Artemisia</i> sp.		sagewart
ASPLENI	<i>Asplenium</i> sp.		spleenwort
ASPLVIR	<i>Asplenium viride</i>		green spleenwort
ATHYFIL	<i>Athyrium filix-femina</i>		lady fern
BLECSP	<i>Blechnum spicant</i>		deer fern
CALLHET	<i>Callitriche heterophylla</i>		diverse-leaved water-starwort
CAMPSCO	<i>Campanula scouleri</i>		Scouler's harebell
CAREX	<i>Carex</i> sp.		sedge
CHIMUMB	<i>Chimaphila umbellata</i>		Prince's pine
CIRSARV	<i>Cirsium arvense</i>		Canada thistle
CIRSNUM	<i>Cirsium</i> sp.		thistle
CORNCAN	<i>Cornus canadensis</i>		bunchberry
CORYDAL	<i>Corydalis</i> sp.		corydalis
CREPCAP	<i>Crepis capillaris</i>		smooth hawksbeard
CYSTFRA	<i>Cystopteris fragilis</i>		fragile fern
DELPMEN	<i>Delphinium menziesii</i>		Menzies' larkspur
DICEFOR	<i>Dicentra formosa</i>		Pacific bleeding heart
DISPHOO	<i>Disporum hookeri</i>		Hooker's fairybells
DRYOEXP	<i>Dryopteris expansa</i>		spiny wood fern
EPILANG	<i>Epilobium angustifolium</i>		fireweed
EPILOBI	<i>Epilobium</i> sp.		willow herb
EQUIARV	<i>Equisetum arvense</i>		common horsetail
EQUISET	<i>Equisetum</i> sp.		horsetail
ERYTHRO	<i>Erythronium</i> sp.		fawn lily
FRAGVES	<i>Fragaria vesca</i>		wood strawberry
FRAGVIR	<i>Fragaria virginiana</i>		wild strawberry
GALITRF	<i>Galium triflorum</i>		sweet-scented bedstraw
GAULSHA	<i>Gaultheria shallon</i>		salal
GERAMOL	<i>Geranium molle</i>		dovefoot geranium
GERANIU	<i>Geranium</i> sp.		geranium
GEUMMAC	<i>Geum macrophyllum</i>		large-leaved avens
GNAPHAL	<i>Gnaphalium</i> sp.		cudweed
GNAPMIC	<i>Gnaphalium microcephalum</i>		slender cudweed
GOODOBL	<i>Goodyera oblongifolia</i>		rattlesnake-plantain
GYMNDRY	<i>Gymnocarpium dryopteris</i>		oak fern
HERACLE	<i>Heracleum</i> sp.		cow-parsnip

Species code	Scientific name	Tree code	Common name
HEUCMIC	<i>Heuchera micrantha</i>		small-flowered alumroot
HIERACI	<i>Hieracium</i> sp.		hawkweed
HOLODIC	<i>Holodiscus discolor</i>		oceanspray
HYPEANA	<i>Hypericum anagalloides</i>		bog St. John's-wort
HYPORAD	<i>Hypochaeris radicata</i>		hairy cat's-ear
JUNCUS	<i>Juncus</i> sp.		rush
LACTMUR	<i>Lactuca muralis</i>		wall lettuce
LACTSER	<i>Lactuca serriola</i>		prickly lettuce
LACTUCA	<i>Lactuca</i> sp.		lettuce
LATHNEV	<i>Lathyrus nevadensis</i>		purple peavine
LEUCVUL	<i>Leucanthemum vulgare</i>		oxeye daisy
LILIACE	<i>Liliaceae</i>		lily
LINNBOR	<i>Linnaea borealis</i>		twinflower
LISTCAU	<i>Listera caurina</i>		northwestern twayblade
LONICER	<i>Lonicera involucrata</i>		black twinberry
LONICIL	<i>Lonicera ciliosa</i>		western trumpet
LUZULA	<i>Luzula</i> sp.		wood-rush
LUZUPAR	<i>Luzula parviflora</i>		small-flowered wood-rush
MAHONER	<i>Mahonia nervosa</i>		dull Oregon-grape
MAIADIL	<i>Maianthemum dilatatum</i>		false lily-of-the-valley
MIMUMOS	<i>Mimulus moschatus</i>		musk-flower
MONOUNI	<i>Monotropa uniflora</i>		Indian-pipe
OENASAR	<i>Oenanthe sarmentosa</i>		Pacific water-parsley
PAXIMYR	<i>Pachistima myrsinites</i>		boxwood
PENTFLO	<i>Potentilla fruticosa</i>		shrubby cinquefoil
PHYSCAP	<i>Physocarpus capitatus</i>		Pacific ninebark
PICESIT	<i>Picea sitchensis</i>	Ss	Sitka spruce
PINUMON	<i>Pinus monticola</i>	Pw	western white pine
PLANLAN	<i>Plantago lanceolata</i>		ribwort plantain
POLYMUN	<i>Polystichum munitum</i>		sword fern
POLYTRI	<i>Polytrichum</i> sp.		haircap moss
PSEUMEN	<i>Pseudotsuga menziesii</i>	Fd	Douglas-fir
PTERAQU	<i>Pteridium aquilinum</i>		bracken fern
PYROASA	<i>Pyrola asarifolia</i>		pink wintergreen
RANUFLA	<i>Ranunculus flabellaris</i>		yellow water-buttercup
RANUUNC	<i>Ranunculus uncinatus</i>		little buttercup
RHAMPUR	<i>Rhamnus purshiana</i>		casara
RIBELAC	<i>Ribes lacustre</i>		black gooseberry
ROSAGYM	<i>Rosa gymnocarpa</i>		baldhip rose
RUBULEU	<i>Rubus leucodermis</i>		black raspberry
RUBUPAR	<i>Rubus parviflorus</i>		thimbleberry
RUBUS	<i>Rubus</i> sp.		raspberry
RUBUSPE	<i>Rubus spectabilis</i>		salmonberry
RUBUURS	<i>Rubus ursinus</i>		trailing blackberry
RUMEACO	<i>Rumex acetosa</i>		green sorrel
SAMBRAC	<i>Sambucus racemosa</i>		red elderberry
SENESYL	<i>Senecio sylvaticus</i>		wood groundsel
SONCASP	<i>Sonchus asper</i>		prickly sow-thistle

Species code	Scientific name	Tree code	Common name
SMILSTE	<i>Smilacina stellata</i>		star-flowered false Solomon's seal
SPIRAEA	<i>Spiraea</i> sp.		spiraea
SPIRDOU	<i>Spiraea douglasii</i>		hardhack
STACCHA	<i>Stachys cooleyae</i>		Cooley's hedge-nettle
STELCAL	<i>Stellaria calycantha</i>		northern starwort
STELLAR	<i>Stellaria</i> sp.		starwort
STREAMP	<i>Streptopus amplexifolius</i>		clasping twistedstalk
STRELAN	<i>Streptopus roseus</i>		rosy twistedstalk
STREPTO	<i>Streptopus</i> sp.		twistedstalk
SYMPALB	<i>Symphoricarpos albus</i>		common snowberry
SYMPHES	<i>Symphoricarpos mollis</i>		trailing snowberry
TARAOFF	<i>Taraxacum officinale</i>		common dandelion
THUJPLI	<i>Thuja plicata</i>	Cw	western redcedar
TIARTRI	<i>Tiarella trifoliata</i>		three-leaved foamflower
TIARTRI	<i>Tiarella laciniata</i>		foamflower
TRIEBOR	<i>Trientalis latifolia</i>		northern starflower
TRIFDUB	<i>Trifolium dubium</i>		small hop-clover
TRIFREP	<i>Trifolium repens</i>		white clover
TRILOVA	<i>Trillium ovatum</i>		western trillium
TSUGHET	<i>Tsuga heterophylla</i>	Hw	western hemlock
VACCINI	<i>Vaccinium</i> sp.		blueberry, huckleberry
VACCMEM	<i>Vaccinium membranaceum</i>		black huckleberry
VACCOVL	<i>Vaccinium ovalifolium</i>		oval-leaved blueberry
VACCPAR	<i>Vaccinium parvifolium</i>		red huckleberry
VEROANA	<i>Veronica anagallis-aquatica</i>		blue water speedwell
VEROBEC	<i>Veronica beccabunga</i>		American speedwell
VEROSER	<i>Veronica serpyllifolia</i>		thyme-leaved speedwell
VIOLA	<i>Viola</i> sp.		violet
VIOLLAC	<i>Viola lanceolata</i>		lance-leaved violet

**APPENDIX 5** List of all B2 and C layer species by treatment unit and disturbance

TU	Disturbance	Layer	Species	Cover (%)
1	1	B2	RUBUSPE	0.205
1	1	B2	VACCPAR	0.102
1	1	B2	PRUNEMA	0.053
1	1	B2	RUBULEU	0.037
1	1	B2	GAULSHA	0.018
1	1	B2	RUBUPAR	0.018
1	1	B2	RUBUSURS	0.017
1	1	B2	SAMBRAS	0.010
1	1	B2	VACCMEM	0.003
1	1	B2	BLECSPI	0.002
1	1	B2	CAREX	0.002
1	1	B2	POLYMUN	0.002
1	1	B2	PTERAQU	0.002
1	1	B2	RUBULAC	0.002
1	1	B2	SALIX SP	0.002
1	1	C	POLYMUN	0.322
1	1	C	GRAMIN	0.307
1	1	C	BLECSPI	0.288
1	1	C	PTERAQU	0.180
1	1	C	CAREX	0.158
1	1	C	EPILANG	0.042
1	1	C	VICIAME	0.030
1	1	C	HYPORAD	0.018
1	1	C	LACTMUR	0.010
1	1	C	TIARTRI	0.007
1	1	C	VACCPAR	0.007
1	1	C	ACHLTRI	0.005
1	1	C	ANAPMAR	0.005
1	1	C	DICEFOR	0.005
1	1	C	GAULSHA	0.005
1	1	C	RUMEACE	0.005
1	1	C	ATHYFIL	0.003
1	1	C	SENESYL	0.003
1	1	C	ATGYFIL	0.002
1	1	C	CIRSARV	0.002
1	1	C	DRYOEXP	0.002
1	1	C	MYEEMUR	0.002
1	1	C	RUBUSPE	0.002
1	1	C	SAMBRAS	0.002
1	1	C	VICAME	0.002
1	1	C	VIOLA	0.002
2	1	B2	RUBUSPE	2.475
2	1	B2	RUBULEU	1.038
2	1	B2	RUBUPAR	0.835
2	1	B2	GRAMIN	0.133
2	1	B2	RUBUURS	0.107
2	1	B2	PRUNEMA	0.082

TU	Disturbance	Layer	Species	Cover (%)
2	1	B2	VACCPAR	0.067
2	1	B2	SAMBRAS	0.065
2	1	B2	ANAPMAR	0.017
2	1	B2	BLECSPI	0.017
2	1	B2	EPILANG	0.017
2	1	B2	POLYMUN	0.017
2	1	B2	GAULSHA	0.007
2	1	B2	HYPORAD	0.002
2	1	B2	LACTMUR	0.002
2	1	B2	RAMNPUR	0.002
2	1	B2	RUBULAC	0.002
2	1	B2	VIOLA	0.002
2	1	C	GRAMIN	1.973
2	1	C	CAREX	1.298
2	1	C	PTERAQU	1.095
2	1	C	DICEFOR	0.702
2	1	C	SENESYL	0.432
2	1	C	POLYMUN	0.425
2	1	C	BLECSPI	0.380
2	1	C	MAHONER	0.233
2	1	C	EPILANG	0.108
2	1	C	HYPORAD	0.083
2	1	C	VICIAME	0.070
2	1	C	RUBUURS	0.050
2	1	C	JUNCSP	0.048
2	1	C	LACTMUR	0.045
2	1	C	ANAPMAR	0.042
2	1	C	RUMEACE	0.038
2	1	C	CIRSARV	0.037
2	1	C	VIOLA	0.037
2	1	C	GNAPMIC	0.010
2	1	C	CIRSVUL	0.008
2	1	C	MYEEMUR	0.003
2	1	C	VICEAME	0.003
2	1	C	DIGIPUR	0.002
2	1	C	GALITRI	0.002
2	1	C	GAULSHA	0.002
2	1	C	RANUREP	0.002
2	1	C	RANUSP	0.002
2	1	C	RUBUPAR	0.002
2	1	C	TSUGHET	0.002
2	1	C	VACCPAR	0.002
2	1	C	VICEANE	0.002
3	0	B2	VACCPAR	0.102
3	0	B2	POLYMUN	0.027
3	0	B2	VACCOVA	0.012
3	0	B2	GAULSHA	0.007
3	0	B2	BLECSPI	0.003
3	0	B2	RUBUSPE	0.003

TU	Disturbance	Layer	Species	Cover (%)
3	0	C	POLYMUN	0.563
3	0	C	BLECSPI	0.200
3	0	C	GYMNDRY	0.025
3	0	C	TIARTRI	0.017
3	0	C	DRYOEXP	0.007
3	0	C	PTERAQU	0.007
3	0	C	VACCPAR	0.007
3	0	C	VIOLA	0.007
3	0	C	VACCOVA	0.003
3	0	C	ATHYFIL	0.002
3	0	C	GALITRI	0.002
3	0	C	GRAMIN	0.002
3	0	C	RANU SP	0.002
3	0	C	STREROS	0.002
3	0	C	TSUGHET	0.002
3	0	C	VICIAME	0.002
4	1	B2	RUBUSPE	1.763
4	1	B2	RUBULEU	0.388
4	1	B2	RUBUPAR	0.320
4	1	B2	RUBUURS	0.193
4	1	B2	VACCPAR	0.113
4	1	B2	PRUNEMA	0.055
4	1	B2	SAMBRAS	0.052
4	1	B2	VACCOVA	0.028
4	1	B2	GAULSHA	0.025
4	1	B2	RUBULAC	0.017
4	1	B2	PINNCON	0.003
4	1	B2	BLECSPI	0.002
4	1	B2	CAREX	0.002
4	1	C	CAREX	0.773
4	1	C	POLYMUN	0.507
4	1	C	GRAMIN	0.380
4	1	C	PTERAQU	0.325
4	1	C	BLECSPI	0.275
4	1	C	EPILANG	0.102
4	1	C	CIRSARV	0.090
4	1	C	HYPORAD	0.052
4	1	C	SENECYL	0.048
4	1	C	ATHYFIL	0.040
4	1	C	ANAPMAR	0.027
4	1	C	VIOLA	0.025
4	1	C	LACTMUR	0.023
4	1	C	GALITRI	0.013
4	1	C	DICEFOR	0.012
4	1	C	TIARTRI	0.010
4	1	C	DRYOEXP	0.008
4	1	C	CIRSVUL	0.005
4	1	C	GNAPMIC	0.005
4	1	C	EQUI SP	0.003



TU	Disturbance	Layer	Species	Cover (%)
4	1	C	GYMNDRY	0.003
4	1	C	SAMBRAS	0.003
4	1	C	ACHLTRI	0.002
4	1	C	GAULSHA	0.002
4	1	C	JUNCSP	0.002
4	1	C	PSEUMEN	0.002
4	1	C	VACCPAR	0.002
5	0	B2	VACCPAR	0.175
5	0	B2	RUBUSPE	0.019
5	0	B2	RUBUPAR	0.014
5	0	B2	GAULSHA	0.008
5	0	B2	PRUNEMA	0.008
5	0	B2	VACCMEM	0.003
5	0	B2	VACCOVA	0.003
5	0	C	BLECSPI	0.492
5	0	C	POLYMUN	0.417
5	0	C	PTERAQU	0.119
5	0	C	GRAMIN	0.022
5	0	C	DRYOEXP	0.011
5	0	C	GOODOBL	0.008
5	0	C	DICEFOR	0.006
5	0	C	TIARTRI	0.006
5	0	C	VIOLA	0.006
5	0	C	ATHYFIL	0.003
5	0	C	RUBUPAR	0.003
5	0	C	RUBUSPE	0.003
5	0	C	VACCPAR	0.003
5	1	B2	RUBUPAR	1.047
5	1	B2	RUBUSPE	0.797
5	1	B2	RUBULEU	0.334
5	1	B2	VACCPAR	0.150
5	1	B2	PRUNEMA	0.025
5	1	B2	GAULSHA	0.022
5	1	B2	SAMBRAS	0.022
5	1	B2	RUBUURS	0.006
5	1	C	PTERAQU	0.844
5	1	C	BLECSPI	0.831
5	1	C	GRAMIN	0.344
5	1	C	POLYMUN	0.300
5	1	C	CAREX	0.147
5	1	C	DICEFOR	0.075
5	1	C	EPILANG	0.072
5	1	C	HYPORAD	0.034
5	1	C	LACTMUR	0.031
5	1	C	ATHYFIL	0.028
5	1	C	ANAPMAR	0.025
5	1	C	DRYOEXP	0.022
5	1	C	VIOLA	0.016
5	1	C	JUNCSP	0.013

TU	Disturbance	Layer	Species	Cover (%)
5	1	C	TIARTRI	0.013
5	1	C	EQUISP	0.006
5	1	C	CIRSARV	0.003
5	1	C	MAIADIL	0.003
5	1	C	SENESYL	0.003
5	1	C	VACCPAR	0.003
6	0	B2	VACCPAR	0.357
6	0	B2	GAULSHA	0.022
6	0	B2	RUBUSPE	0.005
6	0	B2	VACCMEM	0.003
6	0	B2	PRUNEMA	0.002
6	0	C	BLECSPI	2.829
6	0	C	POLYMUN	0.532
6	0	C	VICIAME	0.011
6	0	C	ATHYFIL	0.009
6	0	C	DRYOEXP	0.008
6	0	C	TIARTRI	0.006
6	0	C	GRAMIN	0.005
6	0	C	GOODOBL	0.002
6	0	C	LISTCAU	0.002
6	0	C	PTERAQU	0.002
6	1	B2	VACCPAR	0.211
6	1	B2	RUBUSPE	0.146
6	1	B2	SAMBRAS	0.083
6	1	B2	PRUNEMA	0.034
6	1	B2	RUBULEU	0.034
6	1	B2	RUBUPAR	0.023
6	1	B2	GAULSHA	0.020
6	1	B2	VACCMEM	0.006
6	1	B2	RUBUURS	0.003
6	1	C	BLECSPI	1.117
6	1	C	POLYMUN	0.474
6	1	C	EPILANG	0.091
6	1	C	CAREX	0.051
6	1	C	GRAMIN	0.029
6	1	C	ATHYFIL	0.020
6	1	C	DRYOEXP	0.009
6	1	C	PTERAQU	0.009
6	1	C	SENESYL	0.006
6	1	C	LACTMUR	0.003
7	1	B2	RUBUSPE	0.982
7	1	B2	SAMBRAS	0.491
7	1	B2	VACCPAR	0.451
7	1	B2	RUBULEU	0.367
7	1	B2	RUBUPAR	0.211
7	1	B2	PRUNEMA	0.163
7	1	B2	GAULSHA	0.101
7	1	B2	RUBUURS	0.044
7	1	B2	BLECSPI	0.019

TU	Disturbance	Layer	Species	Cover (%)
7	1	B2	RIBES SP	0.015
7	1	B2	VACCMEM	0.002
7	1	B2	RIBELAC	0.001
7	1	B2	ROSANUT	0.001
7	1	C	BLECSPI	3.025
7	1	C	POLYMUN	0.935
7	1	C	GRAMIN	0.371
7	1	C	EPILANG	0.263
7	1	C	CAREX	0.159
7	1	C	SENESYL	0.086
7	1	C	RUMEACE	0.085
7	1	C	PTERAQU	0.032
7	1	C	HYPORAD	0.025
7	1	C	LACTMUR	0.018
7	1	C	TIARTRI	0.009
7	1	C	ANAPMAR	0.008
7	1	C	JUNCSP	0.007
7	1	C	ACHLTRI	0.005
7	1	C	ATHYFIL	0.004
7	1	C	DICEFOR	0.002
7	1	C	DRYOEXP	0.001
7	1	C	GALITRI	0.001
7	1	C	GAULSHA	0.001
7	1	C	RIBELAC	0.001
7	1	C	RUBULAC	0.001
7	1	C	TRIFREP	0.001